RIGID FRAME BRIDGE DESIGN

A THESIS

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By

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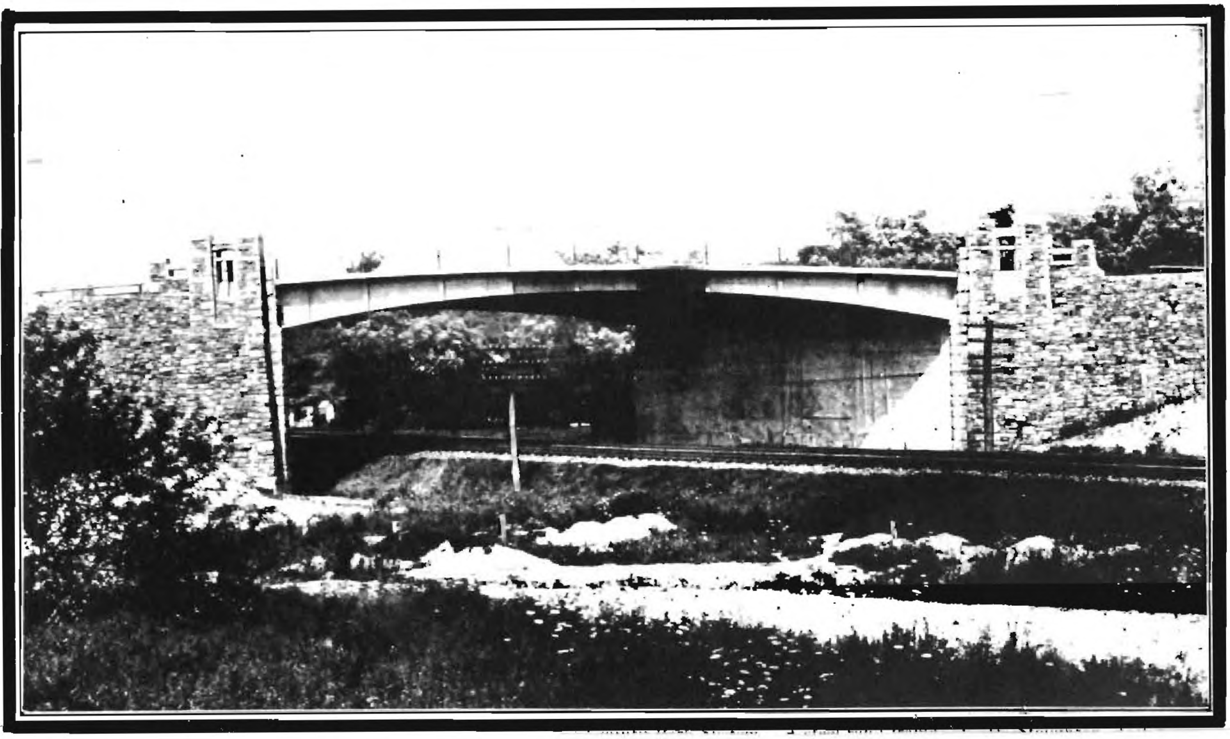
# I N T R O D U C T I O N

## INTRODUCTION

One of the newest and most important developments in the construction of short span bridges is the introduction of the rigid frame principle to their design. This principle has been used for a number of years in other construction but only recently has it been applied to the design of bridges.

Much credit is due to Mr. Arthur G. Hayden, Designing Engineer of the Westchester County Park Commission, New York, and his staff of assistants for their fine work toward developing this theory. Other engineers have contributed greatly toward advance on the subject but Mr. Hayden, by both design and actual construction, has proven beyond a doubt the economy and safety of this type of bridge. The Westchester County Park Commission has constructed many rigid frame bridges of reinforced concrete and structural steel on its magnificent system of parkways and aside from their other advantages, the ease with which the esthetic phases may be developed stands out as a very favorable point.

A glance at the general shape of the rigid frame bridge will suffice to show how admirably it answers all of the requirements for a crossing over an intersecting highway or railroad. It is probably better suited to be used as this type of bridge than any other, although as a crossing over a stream it has the advantage of offering the maximum area of waterway passage for a given length of bridge. Too, the length of span possible is much higher for the rigid frame type of bridge than for the simple slab and girder type and the longer spans are often very highly desirable.



Steel Rigid Frame Bridge.
Westchester County Park System.

Reinforced Concrete Rigid Frame Bridge.
Stone facing helps give this structure a very pleasing appearance.

The design of bridges of this type is based on sound engineering principles and should not be thought of as a mere experiment. The structure, however, is highly indeterminate and the conditions of stress set up in some portions are very complicated. A number of tests have been made in an effort to clarify these conditions but as yet the available data is somewhat meager. The possibilities in the field of experimentation are still great.

Laboratory analyses in attempts to determine the action of the frame under load have been very successful and have contributed greatly to establish confidence in the theoretical approaches used. These tests have been made on small, flat models of some elastic substance, such as celluloid or pasteboard. These models, because of their homogeneity, can be relied upon to yield theoretically correct results which can be applied to actual structures with relatively small error. Further discussion of this method of analysis will be made later.

Bridges of composite materials such as reinforced concrete cannot be expected to act exactly as a more homogeneous body but the inaccuracies in the design assumptions are not sufficient to materially affect the safety of the design. The writer has constructed a reinforced concrete model of a typical rigid frame bridge and by strain gauge measurements under load has gathered some data by which he hopes to prove that the actual stresses developed substantially corroborate those expected from the design.

# THEORY OF THE DESIGN

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From an engineering standpoint the design of a structure is essentially a study of the economics of the situation. This statement must not be construed to mean that all other consideration should be disregarded entirely, because in innumerable cases, the engineer must vary his design greatly to meet architectural and other requirements. It can readily be seen, however, that after determining the essential duties that the structure should be expected to perform, the next step must be to decide in what way all of its functions might be developed with the least possible annual expense. By annual expense is meant not only the initial investment, but also a number of other factors which are very important. Of course, the life of the structure is a most essential consideration as this makes a very great difference in the annual cost. Maintenance, salvage value of materials, interest on investment and insurance premiums must also be considered. The architectural requirements must be weighed against these factors and the design carried out in an effort to give all points their proper consideration.

The rigid frame bridge is adaptable to structural steel and to reinforced concrete. In this paper no effort will be made to compare the relative merits of the two types as this comparison must necessarily be made with reference to a specific case. The essentials of the design are practically the same for bridges of both materials so we may consider the principles involved in the design of one of reinforced concrete and the same general methods could be applied to one of steel.

In the selection of a bridge type, especially for a crossing over an intersecting railroad, street or highway, an important factor to consider is the approach fills at the ends of the bridge. Although not true in every case, the approaches can usually be constructed more economically if the grade is as low as possible. The limiting factor is in most cases the clearance required under the bridge. By using a rigid frame bridge the required clearance can be obtained with very economical approaches. This is true because of the small crown depth of the structure and because the top of the slab can be given a shape to conform to a rising approach from both sides. These advantages are also realized by a flat arch, but the arch must have a much higher rise than the frame type. Because of the greater rise ratio the arch cannot have the same clearance at the haunches as it has at the crown, nor can it keep the same low grade if the clearance at the haunches is increased. Too, the heavy abutments required by the arch are very expensive and their cost is enough to make the rigid frame much more economical.

When a structure is placed under load it is a well knownfact that a deflection is caused and enough work is performed by the structure in supporting the load to exactly equal the product of the load times half of the distance it moves. From this principle the basic economy of the rigid frame can be seen at once. The bridge is so proportioned and built that the deflection of the load is much smaller than it would be on a girder and slab type and hence, the internal work performed is less. Too, the material in the frame can be so efficiently distributed that each portion does some of the work required and no parts are idle.

Also, the deflections produced are such that the fills at the ends of the bridge can be used to help perform the required work, by resisting the deflection at the ends of the structure. All of these design factors combine to make the rigid frame bridge a most economical type and one that is rapidly gaining favor among bridge designers.

The rigid frame bridge is, in all cases, a statically indeterminate structure. The degree of indeterminancy, however, is variable depending on the number of spans and the conditions of the footings. Of course, those of more than one span are highly indeterminate and the mathematical analysis is long and arduous. It has been found by experience that laboratory analyses on elastic models is more practical and can be carried out so much more easily that this method has found preference over the strictly mathematical approach in the case of the multiple span frames. Therefore, no attempt will be made in this paper to present the theoretical design of the more indeterminate cases.

In the single span design two different cases must be considered, each of which requires an entirely different method of approach. The first is when the footings of the bridge rest free upon the foundation material and no bending moment at the footing can be assumed. The other case is when the footings can be so keyed or anchored into the foundation material that a condition of fixity can be assumed. Of course, in many cases some fixity can be secured by the use of foundation piles or other such means, and this would necessarily affect the design. But even though the two types are designed from a different standpoint, the closeness of the results, makes it very easy to take care of both cases with very little loss in economy.

The free end bridge is indeterminate to the first degree since we have two unknown horizontal reaction components and two unknown vertical components with only three static equations with which to solve them. The fixed end bridge is indeterminate to the third degree since, in addition to the unknowns in the other case, it has two unknown moments which makes it have six unknowns in all and only three equations.

The missing equations which are required in order to be able to solve for the unknowns must be provided from a study of the laws of flexure. Let us first consider any small segment of a beam subjected to flexure, as represented by Fig. 1. The length of the segment is s and its original position before bending is shown by the dotted lines.

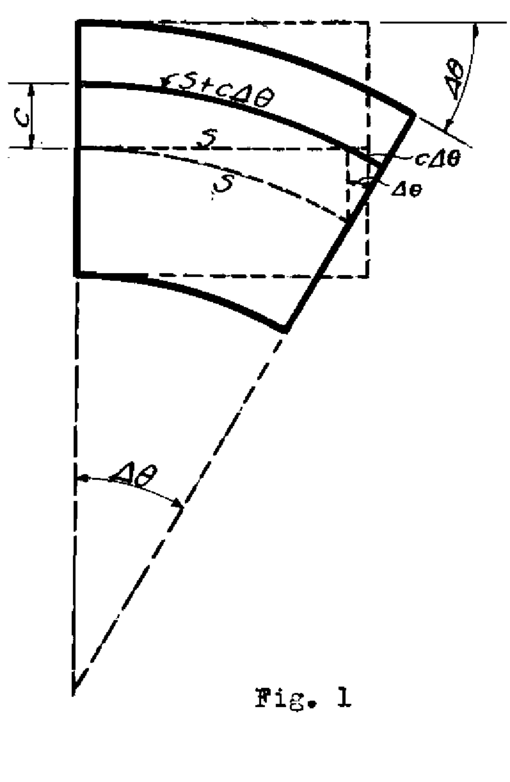


Fig. 1

After bending the segment would take a shape like that shown in heavy lines (of course, greatly exaggerated). The fiber at a distance c from the neutral axis will have elongated by an amount $c\,\Delta\theta$. But from the fact that the modulus of elasticity is equal to the stress divided by the strain, we can say that this elongation is equal to the stress in the fiber times the length of the fiber divided by E or $\frac{sp}{E}$, when p is equal to the stress in the fiber. Now $p = \frac{Mc}{I}$, M being bending moment on the section, so elongation becomes $\frac{Mcs}{EI}$. Equating, $c\,\Delta\theta = \frac{Mcs}{EI}$ or $\Delta\theta = \frac{Ms}{EI}$. This same thing is true of all small segments in a beam so the total change in angle between the tangents at the ends of the beam is the sum of all these small changes or $\sum \frac{Ms}{EI}$.

If the beam were curved before the bending moment was applied, the small segment would appear as shown in Fig. 2. $\theta$ is the angle between the tangents before bending and $\theta'$ is the angle after bending.

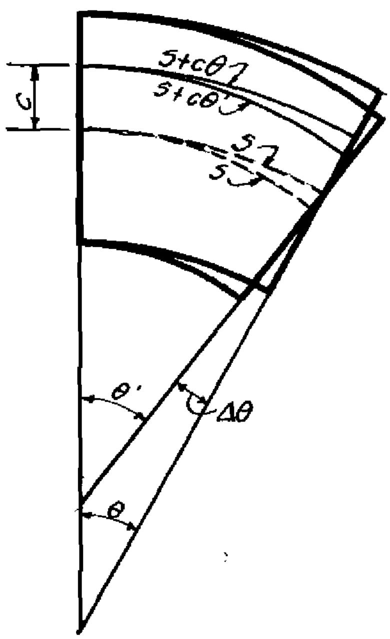



Fig. 2.

If s is the length of the segment at the neutral axis, $s + c\theta$ is the length of a fiber at a distance c from the neutral axis. After flexure the length of the same fiber is $s + c\theta'$. The change of length is $(s + c\theta') - (s + c\theta) = c\Delta\theta$

Assuming again a moment M on the section and a fiber stress of $\frac{Mc}{I}$, we have a change in length of the fiber equal to $\frac{Mc(s + c\theta)}{EI}$.

Letting $c\,\Delta\theta = \frac{Mc(s+c\theta)}{EI}$ or $\frac{Mc}{I} = \frac{c\,\Delta\theta\,E}{s+c} = f$. If we consider this fiber to have a cross-sectional area of a then its moment about the neutral axis is equal to fac or $\frac{ac^2\Delta\theta E}{s + c\theta}$. The resisting moment of

the section being the summation of the moments of all the fibers then $M = \frac{a_c^2 \Delta\theta E}{s + c\theta}$. But the sum of all the infinitesimal cross-sections times the squares of their distances from the neutral axis is the moment of inertia of the section so we can substitute I for $ac^2$ in the above expression. It then becomes $M = \frac{IE\Delta\theta}{s + c\theta}$.
Solving for $\Delta\theta$, we obtain: - $\Delta\theta = \frac{M(s+c\theta)}{IE}$, which might be written also:

$$\Delta\theta = \frac{Ms}{IE}$$ since $s + c\theta$ is practically equal to s for ordinary curvatures in rigid frame or arch ribs. As before, the total change in angle between the tangents at the ends of the axis, $\theta$, is equal to $\sum \frac{Ms}{EI}$.

A rigid frame bridge with free end conditions is, from a design standpoint, similar to a curved beam as shown in Fig. 3.

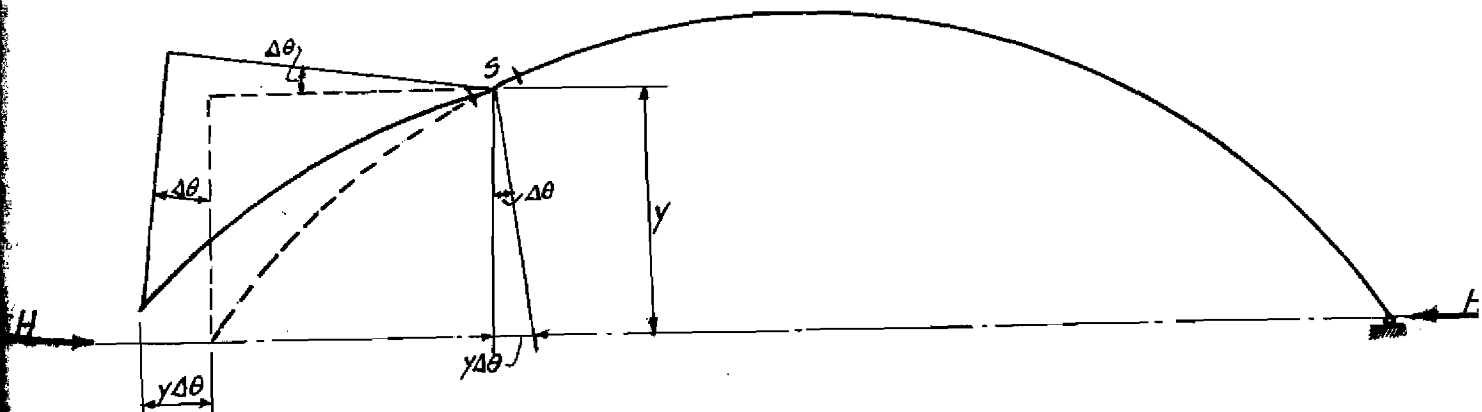



Fig. 3.

Let us first consider that the left end is restrained from lateral movement and the right end is on rollers. Then when the small division s of the axis is subjected to an external bending moment, M, causing a flexure, the angular change between the tangents at its ends, $\Delta\theta$ , is equal to $\frac{Ms}{EI}$. This angular change times the height of the segment, y, is the horizontal displacement of the free end of the beam. The magnitude of this movement is, therefore, equal to $\frac{y\,Ms}{EI}$. From all such segments on the axis of the beam the displacement must be equal to $\sum\frac{y\,Ms}{EI}$. But both ends of the actual beam are restrained from moving and a horizontal force must be acting on the end to cause an equal and opposite displacement to that caused by the externally applied moment. The moment in any segment from this horizontal force is equal to Hy. Then the displacement caused by the horizontal reaction is, as before, $\sum\frac{(Hy)sy}{EI}$ or $\sum\frac{Hy^2s}{EI}$. These two displacements being equal and opposite:

$$\sum\frac{Mys}{EI} - \sum\frac{Hy^2s}{EI} = 0$$

$$\text{or} \quad H = \frac{\sum\frac{Mys}{EI}}{\sum\frac{y^2s}{EI}}$$

$$\text{If E is constant,} \quad H = \frac{\sum\frac{Mys}{I}}{\sum\frac{y^2s}{I}}$$

Now if we so choose our axis divisions that all divisions s are equal, then the equation is further simplified, so that:

$$H = \frac{\sum\frac{My}{I}}{\sum\frac{y^2}{I}}$$

Since the free end frame was indeterminate to only the first degree, this equation gives us all the necessary ones to solve for the reactions and also for the internal stresses after the reactions are found. However, there are other conditions affecting the stresses in the structure. The earth pressure from the fills at the ends of the bridge is very important. This is dealt with as if it were an external load so no further design complications are caused.

Sometimes a change in span length is caused by other factors than a horizontalreaction. Referring again to the equation previously derived:-

$$H = \frac{\sum \frac{Mys}{EI}}{\sum \frac{y^2 s}{EI}}$$

we can notice that the numerator of the right hand side is the expression for total horizontal displacement of the curved beam before the horizontal reaction was applied. If we call this horizontal displacement $\Delta l$, we can let

$$\Delta l = \sum \frac{Mys}{EI} = H \sum \frac{y^2 s}{EI} \quad \text{or}$$

$$\Delta l = \frac{H}{E} \sum \frac{y^2 s}{EI}$$

$$H = \frac{E \Delta l}{\sum \frac{y^2 s}{EI}}$$

The last form is an expression for the horizontal reaction due to any change of span length $\Delta l$.

A change of span length may be caused by a rise or fall in temperature. From the laws of thermal expansion we know that $\Delta l$ would be equal to $ctl$; c being the coefficient of temperature, t being the rise or fall of temperature in degrees, and l being span length.

From our general equation for H we may write

$$H = \frac{E_c t l}{s \sum \frac{y^2}{I}}$$

A rise in temperature is used with a positive sign and a fall with a negative sign, thereby making the results agree with the assumed sign convention; that is, a positive H resists spreading of the footings, a negative H resists a movement toward each other.

Rib shortening is another cause of tendency to change span length. It has an effect similar to a fall in temperature. All thru the rib there is a thrust acting with a normal component N. Letting $f_c$ represent the compression due to N in pounds per square unit on any segment of the rib, we can express the shortening of the segment as $\frac{f_c s}{E}$. Then the shortening of the whole arch is $\sum \frac{f_c s}{E}$. But to find $\Delta l$ we must express this as horizontal displacement, which we can easily do, since the horizontal projection of s is $\Delta x$.

$\therefore$ we may write $\Delta l = \sum \frac{f_c \Delta x}{E}$

Substituting this value for $\Delta l$ into the general equation for change in span length we have $H = \frac{f_c \Delta x}{\sum \frac{y^2 s}{I}}$.

But since s may be assumed constant we have $H = \frac{f_c \Delta x}{s \sum \frac{y^2}{I}}$

With the above equations we are able to carry thru the design of the free end rigid frame, taking into consideration all of the points which affect the design from a practical standpoint.

Next we shall consider the case of the structure with conditions causing restraint at the footings. This structure is indeterminate to the third degree so we must supply three equations from the laws of flexure to supplement the three statical equations which we already have. To do this we may turn to the case of a curved cantilever beam as shown in Fig. 4.

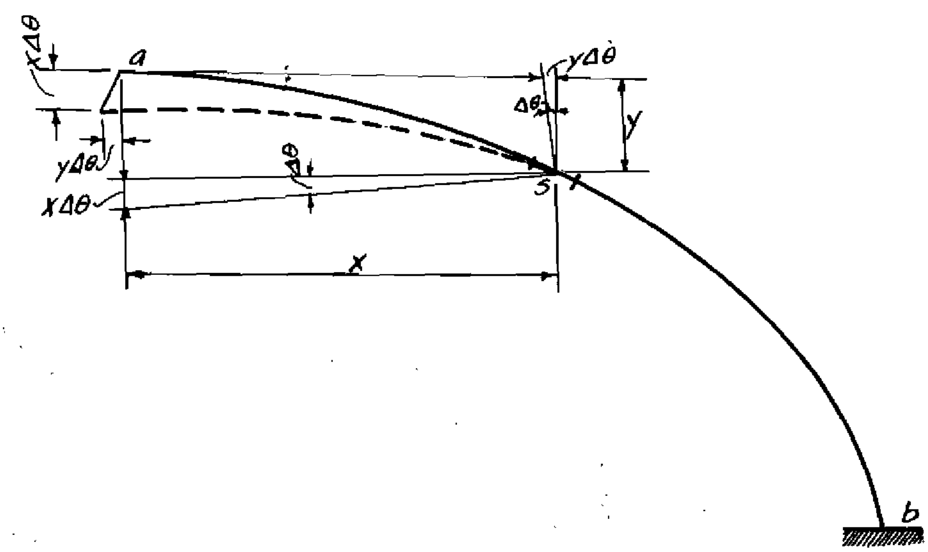



Fig. 4.

If a flexure $\Delta\theta$ is caused in a small segment of length s of the beam, a displacement is caused at the free end. Assuming the origin of coordinates to be at the free end we can express the components of this movement. The horizontal displacement is $y\,\Delta\theta$ and the vertical displacement is $x\,\Delta\theta$ . $\Delta\theta$ is equal to $\frac{Ms}{EI}$ , as shown before, so the components of movement due to the flexure in the small segment are $\frac{Mys}{EI}$ and $\frac{Mxs}{EI}$ . The total horizontal displacement is $\sum\frac{Mys}{EI}$ , the total vertical displacement is $\sum\frac{Mxs}{EI}$ , and the total angular change between the ends is $\sum\frac{Ms}{EI}$ .

The rigid frame bridge with fixed end conditions is similar to that shown in Fig. 5.

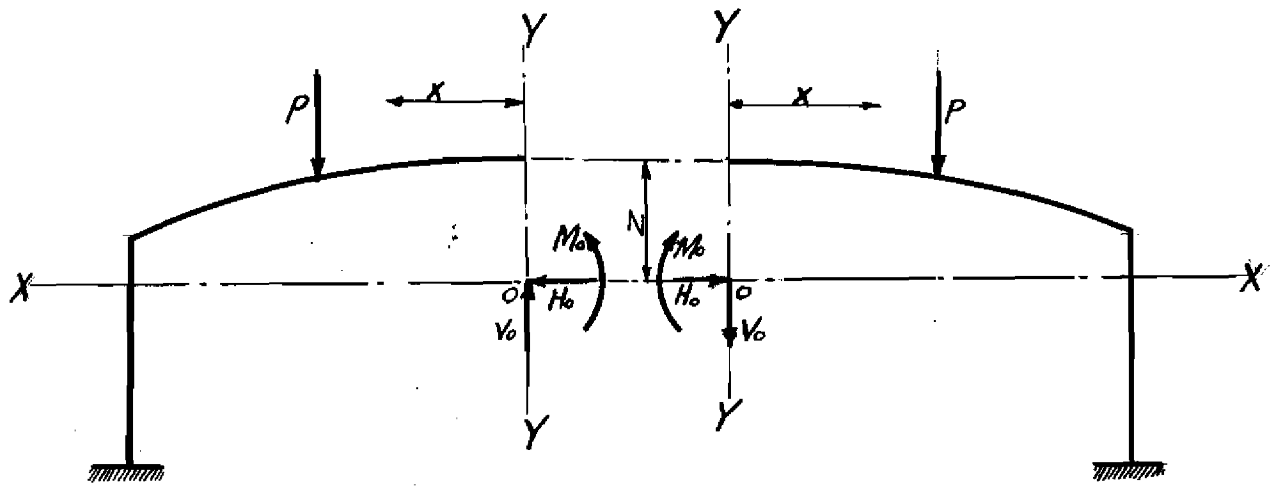



Fig. 5.

As will be seen later the derivation of the equations for this case includes several terms from which $\sum \frac{ys}{EI}$ may be factored. For this reason we can choose our origin of coordinates so as to make this factor equal to O. By making Z of such a value that the XX axis passes thru the center of gravity of the quantities $\frac{s}{I}$, this will be made true and the labor of calculation will be shortened.

By assuming that the bridge is made up of two curved cantilever beams as shown, we can apply the principles of the preceding paragraph. A load p is assumed on each half, which cause a moment on the left half of $M_l$ and one on the right half of $M_r$. The unknown reactions due to the loads are assumed to be applied at the origin of coordinates, and connected to the ends of the beams by an imaginary rigid arm. The deflections caused by the various moments in the beams can be calculated for each half and we know that the two sides will necessarily still coincide. Therefore, we know that the angular change in each cantilever is numerically the same but with opposite signs with relation to the two halves. Likewise the vertical deflections must be equal and with the same sign, and the horizontal deflections are equal but with opposite signs, since one side is elongated and the other one shortened.

The different flexure producing, agencies are, on the left cantilever, $M_l$, $M_o$, V and H. On the right cantilever, they are $M_r$, $M_o$, V and H.

If we equate the horizontal deflections in the two halves we have:-

$$\sum M_l \frac{ys}{EI} + M_o \sum \frac{ys}{EI} + H_o \sum \frac{y^2 s}{EI} + V_o \sum \frac{xys}{EI}$$

$$= -\left[\sum M_r \frac{ys}{EI} + M_o \sum \frac{ys}{EI} + H_o \sum \frac{y^2 s}{EI} - V_o \sum \frac{xys}{EI}\right]$$

This reduces to

$$-2 H_o \sum \frac{y^2 s}{EI} = \sum M_r \frac{ys}{EI} + \sum M_l \frac{ys}{EI}$$

If we cancel the constant E from both sides and also make s constant we may write $-2 H_o \sum \frac{y^2}{I} = \sum M_r \frac{y}{I} + \sum M_l \frac{y}{I}$

We can call $M_r + M_l = M$, which further reduces the equation to:

$$-2 H_o \sum \frac{y^2}{I} = \sum M \frac{y}{I}$$

or $H_o \quad \dfrac{-\sum M \frac{y}{I}}{2 \sum \frac{y^2}{I}}$

In the same way we can express the vertical deflections as:

$$\sum M_l \frac{xs}{EI} + M_o \sum \frac{xs}{EI} + H_o \sum \frac{xys}{EI} + V_o \sum \frac{x^2 s}{EI}$$

$$= \left[\sum M_r \frac{xs}{EI} + M_o\sum \frac{xs}{EI} + H_o\sum\frac{xys}{EI} - V_o\sum\frac{x^2 s}{EI}\right]$$

This reduces to:

$$\sum M_l \frac{xs}{EI} - \sum M_r \frac{xs}{EI} = -2\ V_o\sum\frac{x^2 s}{EI}$$

Taking out E and s as before,

$$\sum M_l \frac{x}{I} - \sum M_r \frac{x}{I} = -2\ V_o\sum\frac{x^2}{I}$$

$$\text{or } V_o = \frac{\sum M_r \frac{x}{I} - \sum M_l \frac{x}{I}}{2\sum\frac{x^2}{I}}$$

The angular change in the ends of the frame can be expressed as follows:

$$\sum M_l \frac{s}{EI} + M_o\sum\frac{s}{EI} + H_o\sum\frac{ys}{EI} + V_o\sum\frac{xs}{EI}$$

$$= -\left[\sum M_r \frac{s}{EI} + M_o\sum\frac{s}{EI} + H_o\sum\frac{ys}{EI} - V_o\sum\frac{xs}{EI}\right]$$

This may be reduced to:

$$\sum M_r \frac{s}{EI} + \sum M_l \frac{s}{EI} = -2\ M_o\sum\frac{s}{EI}$$

$$\text{or} \sum\frac{M}{I} = -2\ M_o\sum\frac{1}{I}$$

$$\text{Solving for } M_o = -\frac{\sum\frac{M}{I}}{2\sum\frac{1}{I}}$$

It must be noticed that all summations are for the half arch except those containing $M$, which must be for the whole arch since they are the combination of similar terms containing $M_l$ and $M_r$.

With these three additional equations we have all that are required to solve for the unknown reactions due to external loads. As before, we can treat the pressure from the fills as any other external load and solve without additional equations.

A change of span length due to some other agency than loads on a structure will cause direct tension or compression and therefore no angular change or vertical reaction. The right hand member of the equation $-2H_o\sum\frac{y^2 s}{EI} = \sum M_r\frac{ys}{EI} + \sum M_1\frac{ys}{EI}$ is an expression for change in span length $\Delta l$, due to any cause whatever. Then:

$$\Delta l = -2H_o\sum\frac{y^2 s}{EI}$$

$$\text{or}\quad H_o = \frac{E\Delta l}{2\sum\frac{y^2 s}{I}} \qquad \text{or} \qquad H_o = \frac{E\Delta l}{2s\sum\frac{y^2}{I}}$$

For stretching of the arch, $\Delta l$ is used with a positive sign and with a negative sign for compressing.

A rise or fall in temperature would cause a change in span length and consequently a horizontal reaction as shown above. $\Delta l$ would be equal to ctl as in the case of the free end frame. If we substitute ctl for $\Delta l$ in the general equation for change in span length, we obtain:

$$H_o = -\frac{Ectl}{2s\sum\frac{y^2}{I}}$$

For this case we must use t as positive for a fall in temperature, since this produces a stretching effect, and negative for a rise in temperature. This is not in accordance with the accepted sign conventions, so if desired we can write the equation,

$$H_o = +\frac{Ectl}{2s\sum\frac{y^2}{I}}$$

and we can use our regular signs for rise and fall in temperature.

Referring back to our calculations for rib shortening in the case of the free end frame we can see that, $\Delta l = \sum \frac{f_c \Delta x}{E}$ .

Substituting this into the general form of the equation for $H_o$, we have $H_o = \frac{-\sum f_c \Delta x}{2_s \sum \frac{y^2}{I}}$

Since rib shortening results in a stretching effect $f_c$ is used with a positive sign, giving us a negative value for $H_o$, that is, acting in the opposite direction from that shown in Fig. 5.

The unsymmetrical frame bridge offers very little additional complications since the theory is exactly the same as for the symmetrical structure. Either one of two expedients may be used and the same results obtained. The horizontal thrust can be assumed to act along

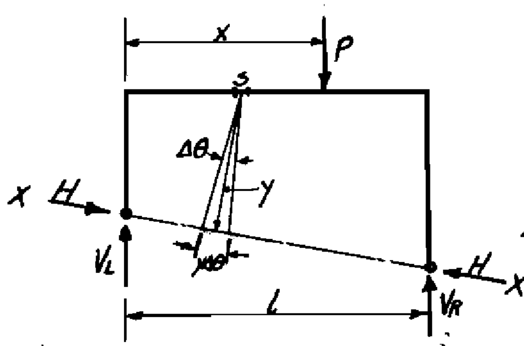



Fig. 6.

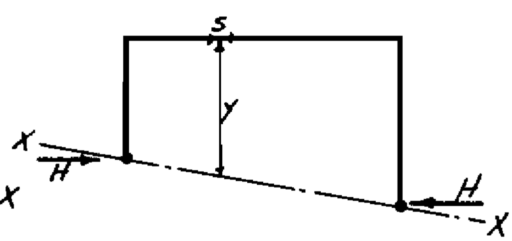



Fig. 7

the XX axis as shown in Fig. 6, and the moments due to it will be equal to Hy, with y measured perpendicular to the XX axis. The thrusts for the second case can be assumed to act horizontally and y measured in a vertical direction to the XX axis. In both cases the bending moments, M are calculated as if the structure were symmetrical. Care should be taken to carry all summations out for the full arch instead of the half arch as in the case of the symmetrical span.

# PRACTICAL APPLICATION OF DESIGN

## PRACTICAL APPLICATION OF DESIGN

From experience the rigid frame bridge has been found economical for span lengths of from 35 ft. to 80 ft. for reinforced concrete and from 80 ft. to 120 ft. for steel. As yet, however, experience has not determined any rigid limits of economy and comparisons must still be resorted to in order to determine the advisability of this type for a specific structure.

The design of a reinforced concrete bridge with free end conditions is carried thru in this paper and an attempt is made to show the application of the design principles as would be required in practice. The structure has been assumed to rest free upon the soil with the resultant earth pressure acting near the center of the base. The sketch of the half frame is shown in Fig. 8.

The structure chosen to illustrate the design has a span length of 81 ft. The lengths of the divisions s were made 3 ft., starting at the center of the span. This makes the divisions at the bottoms of the vertical legs of a different length but the values derived for them may be weighted in proportion to their length and correct results will be obtained. As a matter of fact, however, these bottom divisions have very little influence on the rest of the arch, and ignoring them makes little difference in the results. It can be noticed that a center of division point occurs at the bend in the knee. The divisions should be so made that this condition will prevail since this is the point of maximum negative moment and the stress conditions at this point should be obtained. The structure has such a flat curve that the horizontal projections of the divisions s can also be assumed as 3 ft., and this saves us some labor in the calculations.

For convenience in calculations the origin of coordinates is assumed at the bottom of one of the legs at the imaginary hinge joint. The reactions are first assumed to act as in Fig. 8. Upon calculation, if they come out positive they will act in that direction, and if negative, in the opposite direction. All moments, due to either external loads or to reaction components, are tabulated positive if they conform to the regular sign convention for positive moments; i. e., producing compression on the outside fibers of the arch.

The procedure in the design is to assume first a general shape of the arch ring and reinforcing throughout. Then the moments of inertia can be computed and the frame constants determined.

Then by using influence loads at each center of division we can compute the moments at all points on the span by using our equations previously mentioned. The labor of working out the effects of these influence loads can be shortened by assuming a load greater than unity and of such a value that the smallest simple beam moment that must be dealt with is equal to 1. In the case under discussion the influence load used was 9 and this gave us a moment at Pt. $10_l$ due to a load at $10_r$ of:

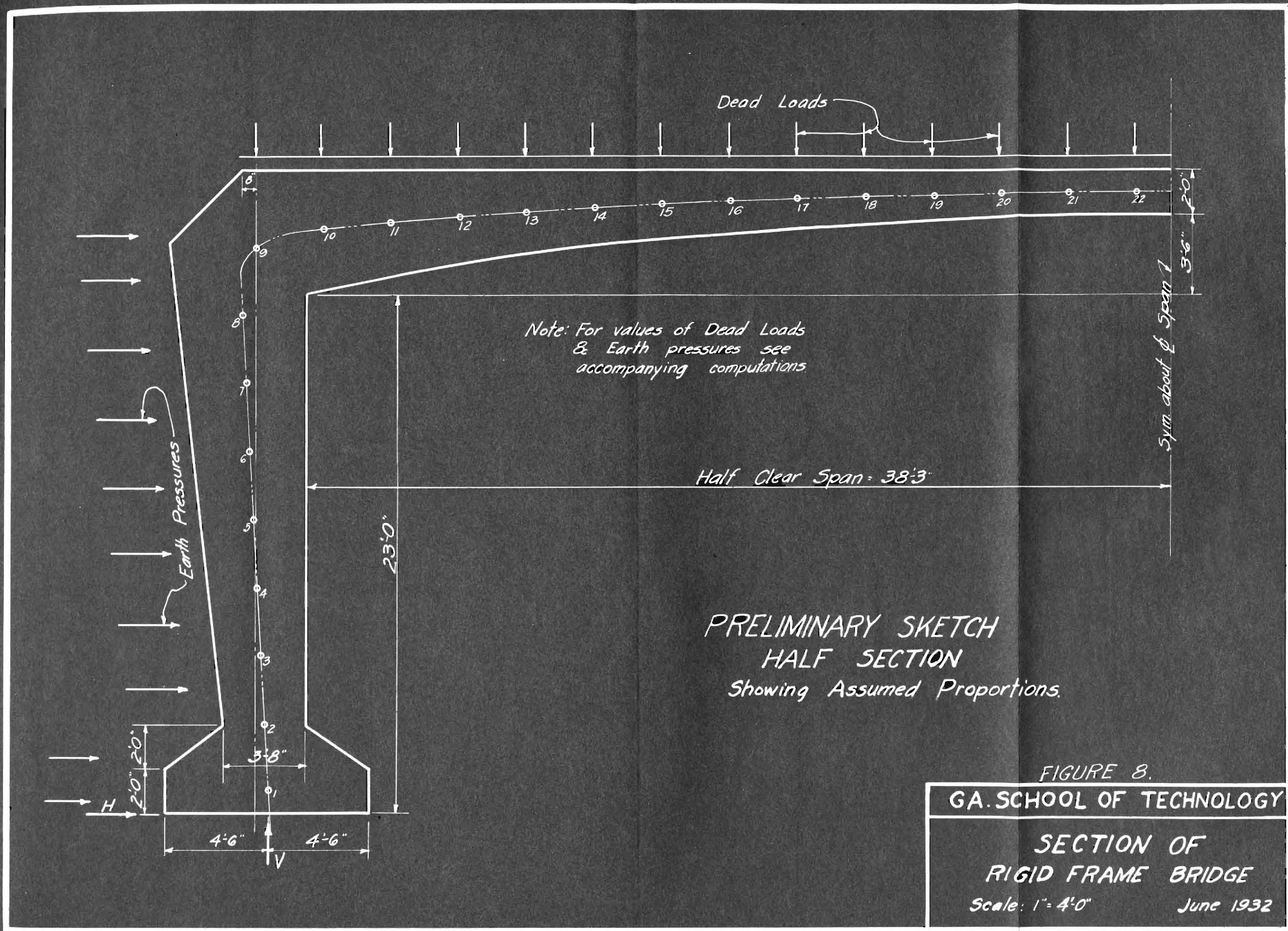
$$1/27 \times 9 \times 3 = 1$$

Of course, the influence curves must be plotted to such a scale that we can read off 1/9 of the calculated values and get the influence curves for moment and thrust for a unit load.

After the influence lines have been constructed the work of finding the moments due to dead and live loads and also the normal thrusts is very easily accomplished. Then the same things are computed for the earth pressure, temperature stresses and rib shortening using the formulas already derived. The maximum positive and negative moments with their corresponding normal thrusts are then tabulated and the calculations for reinforcing at each section are carried thru. These calculations are made using the formulas for combined bending and direct stress. Much labor can be saved by using the table which is included in Hool and Johnson's Concrete Engineer's Handbook.

Some corrections may be necessary in the assumed sections in order to keep an economical design or to keep the stresses within the safe working limits. Sometimes compression reinforcement at the crown is economical in order to keep the crown depth low or to keep from over reinforcing for tension. Variations in assumed moments of inertia might vary as much as 20 per cent without seriously affecting the safety of the design. However, large variations in the moments of inertia should call for a recalculation.

Following is the complete set of calculations for the symmetrical rigid frame bridge with hinged conditions at the footings. It will be noticed in the design, Fig. 9, that stirrups are used in the rib of the arch. These stirrups are serving not as calculated shear reinforcing, but to support the extrados steel and to furnish an additional factor of safety in carrying the shear. Also, nominal reinforcing is used in the inside or soffit face of the vertical legs, although none is required from the calculations. Transverse tie rods are also used to prevent formation of cracks due to unequal settlement and other causes.


Dead Loads
6"
2'0"
3'6"
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Note: For values of Dead Loads & Earth pressures see accompanying computations.
Sym. about ℄ Span
Earth Pressures
Half Clear Span = 38'3"
23'0"
3'8"
2'0"
2'0"
H
V
4'6"
4'6"
PRELIMINARY SKETCH
HALF SECTION
Showing Assumed Proportions.
GA. SCHOOL OF TECHNOLOGY
SECTION OF
RIGID FRAME BRIDGE
Scale: 1" = 4'0"
June 1932
FIGURE 8.

| Point | $t$ Feet | $I_c$ $\frac{1}{12}t^3$ | $A_s$ Sq.Ft. | $D$ $\frac{t}{2} - .17$ | $I_s$ $10A_sD^2$ | $I$ $I_c + I_s$ | $Y$ | $\frac{Y^2}{I}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.0 | 60.75 | 0.0070 | 4.33 | 1.31 | 62.06 | 1.0 | 0.02 |
| 2 | 3.67 | 4.12 | 0.0140 | 1.67 | 0.39 | 4.51 | 4.0 | 3.55 |
| 3 | 4.00 | 5.33 | 0.0140 | 1.83 | 0.47 | 5.80 | 7.0 | 8.45 |
| 4 | 4.33 | 6.76 | 0.0140 | 2.00 | 0.56 | 7.32 | 10.0 | 13.66 |
| 5 | 4.69 | 8.60 | 0.0245 | 2.18 | 1.16 | 9.76 | 13.0 | 17.32 |
| 6 | 5.02 | 10.52 | 0.0245 | 2.34 | 1.34 | 11.86 | 16.0 | 21.59 |
| 7 | 5.35 | 12.75 | 0.0245 | 2.51 | 1.54 | 14.29 | 19.0 | 25.26 |
| 8 | 5.69 | 15.34 | 0.0245 | 2.68 | 1.76 | 17.10 | 22.0 | 28.30 |
| 9 | 6.00 | 18.00 | 0.0245 | 2.83 | 1.96 | 19.96 | 25.0 | 31.31 |
| 10 | 5.33 | 12.61 | 0.0245 | 2.50 | 1.53 | 14.14 | 25.87 | 47.33 |
| 11 | 4.75 | 8.93 | 0.0176 | 2.21 | 0.86 | 9.79 | 26.16 | 69.89 |
| 12 | 4.21 | 6.21 | 0.0176 | 1.94 | 0.66 | 6.87 | 26.42 | 101.60 |
| 13 | 3.75 | 4.39 | 0.0176 | 1.71 | 0.51 | 4.90 | 26.65 | 144.94 |
| 14 | 3.37 | 3.19 | 0.0217 | 1.52 | 0.50 | 3.69 | 26.84 | 195.20 |
| 15 | 3.08 | 2.44 | 0.0217 | 1.37 | 0.41 | 2.85 | 26.98 | 255.40 |
| 16 | 2.83 | 1.89 | 0.0217 | 1.25 | 0.34 | 2.23 | 27.10 | 333.81 |
| 17 | 2.58 | 1.43 | 0.0217 | 1.12 | 0.27 | 1.70 | 27.22 | 435.84 |
| 18 | 2.42 | 1.18 | 0.0326 | 1.04 | 0.35 | 1.53 | 27.30 | 487.12 |
| 19 | 2.25 | .95 | 0.0326 | 0.96 | 0.30 | 1.25 | 27.38 | 599.68 |
| 20 | 2.08 | .75 | 0.0326 | 0.87 | 0.25 | 1.00 | 27.46 | 754.05 |
| 21 | 2.00 | .67 | 0.0326 | 0.83 | 0.22 | 0.89 | 27.50 | 849.72 |
| 22 | 2.00 | .67 | 0.0326 | 0.83 | 0.22 | 0.89 | 27.50 | 849.72 |

$\sum \frac{Y^2}{I}$ = 5273.76 for half span

10,547.52 for full span

LOAD = 9

| Point | I | y | Influence Load at 10 L: Mom. | $\frac{My}{I}$ | Hy | Total M | Point |
|---|---|---|---|---|---|---|---|
| 1L | 62.06 | 1.0 | 0 | 0 | - .48 | - .48 | 1L |
| 2L | 4.51 | 4.0 | 0 | 0 | 1.92 | 1.92 | 2L |
| 3L | 5.80 | 7.0 | 0 | 0 | 3.36 | 3.36 | 3L |
| 4L | 7.32 | 10.0 | 0 | 0 | 4.80 | 4.80 | 4L |
| 5L | 9.76 | 13.0 | 0 | 0 | 6.24 | 6.24 | 5L |
| 6L | 11.86 | 16.0 | 0 | 0 | 7.68 | 7.68 | 6L |
| 7L | 14.29 | 19.0 | 0 | 0 | 9.12 | 9.12 | 7L |
| 8L | 17.10 | 22.0 | 0 | 0 | 10.56 | 10.56 | 8L |
| 9L | 19.96 | 25.0 | 0 | 0 | 12.00 | 12.00 | 9L |
| 10L | 14.14 | 25.87 | 26 | 47.57 | +13.58 | +13.58 | 10L |
| 11L | 9.79 | 26.16 | 25 | 66.80 | 12.44 | 12.44 | 11L |
| 12L | 6.87 | 26.42 | 24 | 92.30 | 11.32 | 11.32 | 12L |
| 13L | 4.90 | 26.65 | 23 | 125.09 | 10.21 | 10.21 | 13L |
| 14L | 3.69 | 26.84 | 22 | 160.02 | 9.12 | 9.12 | 14L |
| 15L | 2.85 | 26.98 | 21 | 198.76 | 8.05 | 8.05 | 15L |
| 16L | 2.23 | 27.10 | 20 | 243.05 | 6.99 | 6.99 | 16L |
| 17L | 1.70 | 27.22 | 19 | 304.22 | 5.93 | 5.93 | 17L |
| 18L | 1.53 | 27.30 | 18 | 321.16 | 4.90 | 4.90 | 18L |
| 19L | 1.25 | 27.38 | 17 | 372.37 | 3.86 | 3.86 | 19L |
| 20L | 1.00 | 27.46 | 16 | 439.36 | 2.82 | 2.82 | 20L |
| 21L | 0.89 | 27.50 | 15 | 463.48 | 1.80 | 1.80 | 21L |
| 22L | 0.89 | 27.50 | 14 | 432.58 | + .80 | + .80 | 22L |
| 22R | 0.89 | 27.50 | 13 | 401.68 | - .20 | - .20 | 22R |
| 21R | 0.89 | 27.50 | 12 | 370.79 | -1.20 | - 1.20 | 21R |
| 20R | 1.00 | 27.46 | 11 | 302.06 | 2.18 | 2.18 | 20R |
| 19R | 1.25 | 27.38 | 10 | 219.04 | 3.14 | 3.14 | 19R |
| 18R | 1.53 | 27.30 | 9 | 160.58 | 4.10 | 4.10 | 18R |
| 17R | 1.70 | 27.22 | 8 | 128.10 | 5.07 | - 5.07 | 17R |
| 16R | 2.23 | 27.10 | 7 | 85.07 | 6.01 | 6.01 | 16R |
| 15R | 2.85 | 26.98 | 6 | 56.80 | 6.95 | 6.95 | 15R |
| 14R | 3.69 | 26.84 | 5 | 36.37 | 7.88 | 7.88 | 14R |
| 13R | 4.90 | 26.65 | 4 | 21.75 | 8.79 | 8.79 | 13R |
| 12R | 6.87 | 26.42 | 3 | 11.54 | 9.68 | 9.68 | 12R |
| 11R | 9.79 | 26.16 | 2 | 5.34 | 10.56 | 10 .56 | 11R |
| 10R | 14.14 | 25.87 | 1 | 1.83 | 11.42 | 11.42 | 10R |
| 9R | 19.96 | 25.0 | 0 | 0 | 12.00 | 12.00 | 9R |
| 8R | 17.10 | 22.0 | 0 | 0 | 10.56 | 10.56 | 8R |
| 7R | 14.29 | 19.0 | 0 | 0 | 9.12 | 9.12 | 7R |
| 6R | 11.86 | 16.0 | 0 | 0 | 7.68 | 7.68 | 6R |
| 5R | 9.76 | 13.0 | 0 | 0 | 6.24 | 6.24 | 5R |
| 4R | 7.32 | 10.0 | 0 | 0 | 4.80 | 4.80 | 4R |
| 3R | 5.80 | 7.0 | 0 | 0 | 3.36 | 3.36 | 3R |
| 2R | 4.51 | 4.0 | 0 | 0 | 1.92 | 1.92 | 2R |
| 1R | 62.06 | 1.0 | 0 | 0 | - .48 | - .48 | 1R |

$\Sigma = 5067.71$

$$H = \frac{\sum \frac{My}{I}}{\sum \frac{Y^2}{I}} = \frac{5067.71}{10,547.52}$$

$H = .48$

Load = 9

| Point | Influence Load at 11L Mom. | $\frac{My}{I}$ | Hy | Total M |
|---|---|---|---|---|
| 1L | 0 | 0 | - .96 | - .96 |
| 2L | 0 | 0 | 3.84 | 3.84 |
| 3L | 0 | 0 | 6.72 | 6.72 |
| 4L | 0 | 0 | 9.60 | 9.60 |
| 5L | 0 | 0 | 12.48 | 12.48 |
| 6L | 0 | 0 | 15.36 | 15.36 |
| 7L | 0 | 0 | 18.24 | 18.24 |
| 8L | 0 | 0 | 21.12 | 21.12 |
| 9L | 0 | 0 | 24.00 | -24.00 |
| 10L | 25 | 45.73 | 24.85 | + .15 |
| 11L | 50 | 133.61 | 25.10 | 24.90 |
| 12L | 48 | 184.60 | 25.40 | 22.60 |
| 13L | 46 | 250.18 | 25.60 | 20.40 |
| 14L | 44 | 320.04 | 25.79 | 18.21 |
| 15L | 42 | 397.52 | 25.90 | 16.10 |
| 16L | 40 | 486.10 | 26.02 | 13.98 |
| 17L | 38 | 608.44 | 26.18 | 11.82 |
| 18L | 36 | 642.32 | 26.21 | 9.79 |
| 19L | 34 | 744.74 | 26.25 | 7.75 |
| 20L | 32 | 878.72 | 26.36 | 5.64 |
| 21L | 30 | 926.96 | 26.40 | 3.60 |
| 22L | 28 | 865.16 | 26.40 | +1.50 |
| 22R | 26 | 803.36 | 26.40 | - .40 |
| 21R | 24 | 741.58 | 26.40 | 2.40 |
| 20R | 22 | 604.12 | 26.36 | 4.36 |
| 19R | 20 | 438.08 | 26.25 | 6.25 |
| 18R | 18 | 321.16 | 26.21 | 8.21 |
| 17R | 16 | 256.20 | 26.18 | 10.18 |
| 16R | 14 | 170.14 | 26.02 | 12.02 |
| 15R | 12 | 113.60 | 25.90 | 13.90 |
| 14R | 10 | 72.74 | 25.79 | 15.79 |
| 13R | 8 | 43.50 | 25.60 | 17.60 |
| 12R | 6 | 23.08 | 25.40 | 19.40 |
| 11R | 4 | 10.68 | 26.10 | 21.10 |
| 10R | 2 | 3.66 | 24.85 | 22.85 |
| 9R | 0 | 0 | 24.00 | 24.00 |
| 8R | 0 | 0 | 21.12 | 21.12 |
| 7R | 0 | 0 | 18.24 | 18.24 |
| 6R | 0 | 0 | 15.36 | 15.36 |
| 5R | 0 | 0 | 12.48 | 12.48 |
| 4R | 0 | 0 | 9.60 | 9.60 |
| 3R | 0 | 0 | 6.72 | 6.72 |
| 2R | 0 | 0 | 3.84 | 3.84 |
| 1R | 0 | 0 | - .96 | - .96 |
| | | = 10086.02 | | |

$$H = \frac{\frac{My}{I}}{\frac{y^2}{I}} = \frac{10,086.02}{10,547.52}$$

H = .96

Load = 9

| Point | Influence Load at 12L Mom. | $\frac{My}{I}$ | Hy | Total M |
|---|---|---|---|---|
| 1L | 0 | 0 | -1.43 | -1.43 |
| 2L | 0 | 0 | 5.72 | 5.72 |
| 3L | 0 | 0 | 10.01 | 10.01 |
| 4L | 0 | 0 | 14.30 | 14.30 |
| 5L | 0 | 0 | 18.59 | 18.59 |
| 6L | 0 | 0 | 22.88 | 22.88 |
| 7L | 0 | 0 | 27.17 | 27.17 |
| 8L | 0 | 0 | 31.46 | 31.46 |
| 9L | 0 | 0 | 35.75 | 35.75 |
| 10L | 24 | 43.92 | 37.99 | -13.99 |
| 11L | 48 | 128.26 | 37.41 | +10.59 |
| 12L | 72 | 276.91 | 37.78 | 34.22 |
| 13L | 69 | 375.29 | 38.11 | 30.89 |
| 14L | 66 | 480.08 | 38.38 | 27.62 |
| 15L | 63 | 596.42 | 38.58 | 24.42 |
| 16L | 60 | 729.12 | 38.75 | 21.25 |
| 17L | 57 | 912.68 | 38.92 | 18.08 |
| 18L | 54 | 963.52 | 39.04 | 14.96 |
| 19L | 51 | 1117.10 | 39.15 | 11.85 |
| 20L | 48 | 1318.08 | 39.27 | 8.73 |
| 21L | 45 | 1390.45 | 39.33 | 5.67 |
| 22L | 42 | 1297.78 | 39.33 | +2.67 |
| 22R | 39 | 1205.06 | 39.33 | - .33 |
| 21R | 36 | 1112.36 | 39.33 | 3.33 |
| 20R | 33 | 906.18 | 39.27 | 6.27 |
| 19R | 30 | 657.12 | 39.15 | 9.15 |
| 18R | 27 | 481.76 | 39.04 | 12.04 |
| 17R | 24 | 384.29 | 38.92 | 14.92 |
| 16R | 21 | 255.19 | 38.75 | 17.75 |
| 15R | 18 | 170.41 | 38.58 | 20.58 |
| 14R | 15 | 109.10 | 38.38 | 23.38 |
| 13R | 12 | 65.27 | 38.11 | 26.11 |
| 12R | 9 | 34.61 | 37.78 | 28.78 |
| 11R | 6 | 16.03 | 37.41 | 31.41 |
| 10R | 3 | 5.49 | 37.99 | 34.99 |
| 9R | 0 | 0 | 35.75 | 35.75 |
| 8R | 0 | 0 | 31.46 | 31.46 |
| 7R | 0 | 0 | 27.17 | 27.17 |
| 6R | 0 | 0 | 22.88 | 22.88 |
| 5R | 0 | 0 | 18.59 | 18.59 |
| 4R | 0 | 0 | 14.30 | 14.30 |
| 3R | 0 | 0 | 10.01 | 10.01 |
| 2R | 0 | 0 | 5.72 | 5.72 |
| 1R | 0 | 0 | -1.43 | -1.43 |

= 15,032.46

$$H = \frac{\frac{My}{I}}{\frac{y^2}{I}} = \frac{15,032.46}{10,547.52}$$

H = 1.43

Load = 9

| Point | Mom. | $\frac{My}{I}$ | Hy | Total M |
|---|---|---|---|---|
| | INFLUENCE LOAD AT 13L | | | |
| 1L | 0 | 0 | - 1.88 | -1.88 |
| 2L | 0 | 0 | 7.52 | 7.52 |
| 3L | 0 | 0 | 13.16 | 13.16 |
| 4L | 0 | 0 | 18.80 | 18.80 |
| 5L | 0 | 0 | 24.44 | 24.44 |
| 6L | 0 | 0 | 30.08 | 30.08 |
| 7L | 0 | 0 | 35.72 | 35.72 |
| 8L | 0 | 0 | 41.36 | 41.36 |
| 9L | 0 | 0 | 47.00 | 47.00 |
| 10L | 23 | 42.09 | 48.64 | 25.64 |
| 11L | 46 | 122.91 | 49.18 | -3.18 |
| 12L | 69 | 265.37 | 49.67 | +19.33 |
| 13L | 92 | 500.39 | 50.10 | 41.90 |
| 14L | 88 | 640.11 | 50.46 | 37.54 |
| 15L | 84 | 793.23 | 50.72 | 33.28 |
| 16L | 80 | 972.16 | 50.95 | 29.05 |
| 17L | 76 | 1216.91 | 51.17 | 24.83 |
| 18L | 72 | 1284.70 | 51.32 | 20.68 |
| 19L | 68 | 1489.47 | 51.47 | 16.53 |
| 20L | 64 | 1757.44 | 51.62 | 12.38 |
| 21L | 60 | 1853.94 | 51.70 | 8.30 |
| 22L | 56 | 1730.34 | 51.70 | 4.30 |
| 22R | 52 | 1606.75 | 51.70 | + .30 |
| 21R | 48 | 1483.15 | 51.70 | - 3.70 |
| 20R | 44 | 1208.24 | 51.62 | 7.62 |
| 19R | 40 | 876.16 | 51.47 | 11.47 |
| 18R | 36 | 642.35 | 51.32 | 15.32 |
| 17R | 32 | 512.38 | 51.17 | 19.17 |
| 16R | 28 | 340.26 | 50.95 | 22.95 |
| 15R | 24 | 227.21 | 50.72 | 26.72 |
| 14R | 20 | 145.48 | 50.46 | 30.46 |
| 13R | 16 | 87.02 | 50.10 | 34.10 |
| 12R | 12 | 46.15 | 49.67 | 37.67 |
| 11R | 8 | 21.38 | 49.18 | 41.18 |
| 10R | 4 | 7.32 | 48.64 | 44.64 |
| 9R | 0 | 0 | 47.00 | 47.00 |
| 8R | 0 | 0 | 41.36 | 41.36 |
| 7R | 0 | 0 | 35.72 | 35.72 |
| 6R | 0 | 0 | 30.08 | 30.08 |
| 5R | 0 | 0 | 24.44 | 24.44 |
| 4R | 0 | 0 | 18.80 | 18.80 |
| 3R | 0 | 0 | 13.16 | 13.16 |
| 2R | 0 | 0 | 7.52 | 7.52 |
| 1R | 0 | 0 | -1.88 | - 1.88 |

$\Sigma$ = 19872.91

$$H = \frac{\sum \frac{My}{I}}{\sum \frac{y^2}{I}} = \frac{19,872.91}{10547.52} = 1.88$$

Load = 9

| Point | INFLUENCE LOAD AT 14 L | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total M |
| 1L | 0 | 0 | 2.33 | -2.33 |
| 2L | 0 | 0 | 9.32 | 9.32 |
| 3L | 0 | 0 | 16.31 | 16.31 |
| 4L | 0 | 0 | 23.30 | 23.30 |
| 5L | 0 | 0 | 30.29 | 30.29 |
| 6L | 0 | 0 | 37.28 | 37.28 |
| 7L | 0 | 0 | 44.27 | 44.27 |
| 8L | 0 | 0 | 51.26 | 51.26 |
| 9L | 0 | 0 | 58.25 | 58.25 |
| 10L | 22 | 40.26 | 60.28 | 38.28 |
| 11L | 44 | 117.57 | 60.95 | -16.95 |
| 12L | 66 | 253.84 | 61.56 | ≠ 4.44 |
| 13L | 88 | 478.63 | 62.09 | 25.91 |
| 14L | 110 | 800.14 | 62.54 | 47.46 |
| 15L | 105 | 994.04 | 62.86 | 42.14 |
| 16L | 100 | 1215.20 | 63.14 | 36.86 |
| 17L | 95 | 1521.14 | 63.42 | 31.58 |
| 18L | 90 | 1605.87 | 63.61 | 26.39 |
| 19L | 85 | 1861.92 | 63.80 | 21.20 |
| 20L | 80 | 2196.80 | 63.98 | 16.02 |
| 21L | 75 | 2317.43 | 64.08 | 10.92 |
| 22L | 70 | 2162.93 | 64.08 | 5.92 |
| 22R | 65 | 2008.44 | 64.08 | ≠ .92 |
| 21R | 60 | 1853.94 | 64.08 | - 4.08 |
| 20R | 55 | 1510.30 | 63.98 | 8.98 |
| 19R | 50 | 1095.20 | 63.80 | 13.80 |
| 18R | 45 | 802.94 | 63.61 | 18.61 |
| 17R | 40 | 640.48 | 63.42 | 23.42 |
| 16R | 35 | 425.32 | 63.14 | 28.14 |
| 15R | 30 | 284.01 | 62.86 | 32.86 |
| 14R | 25 | 181.85 | 62.59 | 37.54 |
| 13R | 20 | 108.78 | 62.09 | 42.09 |
| 12R | 15 | 57.69 | 61.56 | 46.56 |
| 11R | 10 | 26.72 | 60.95 | 50.95 |
| 10R | 5 | 9.15 | 60.28 | 55.28 |
| 9R | 0 | 0 | 58.25 | 58.25 |
| 8R | 0 | 0 | 51.26 | 51.26 |
| 7R | 0 | 0 | 44.27 | 44.27 |
| 6R | 0 | 0 | 37.28 | 37.28 |
| 5R | 0 | 0 | 30.29 | 30.29 |
| 4R | 0 | 0 | 23.30 | 23.30 |
| 3R | 0 | 0 | 16.31 | 16.31 |
| 2R | 0 | 0 | 9.32 | 9.32 |
| 1R | 0 | 0 | 2.33 | 2.33 |

$\Sigma$ = 24,570.59

$$H = \frac{\sum \frac{My}{I}}{\sum \frac{y^2}{I}} = \frac{24,570.59}{10547.52} = 2.33$$

LOAD = 9

| Point | Influence Load at 15L | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total M |
| 1L | 0 | 0 | - 2.76 | - 2.76 |
| 2L | 0 | 0 | 11.04 | -11.04 |
| 3L | 0 | 0 | 19.32 | 19.32 |
| 4L | 0 | 0 | 27.60 | 27.60 |
| 5L | 0 | 0 | 35.88 | 35.88 |
| 6L | 0 | 0 | 44.16 | 44.16 |
| 7L | 0 | 0 | 52.44 | 52.44 |
| 8L | 0 | 0 | 60.72 | 60.72 |
| 9L | 0 | 0 | 69.00 | 69.00 |
| 10L | 21 | 38.43 | 71.40 | 50.40 |
| 11L | 42 | 112.22 | 72.20 | 30.20 |
| 12L | 63 | 242.30 | 72.92 | - 9.92 |
| 13L | 84 | 456.88 | 73.55 | +10.45 |
| 14L | 105 | 763.77 | 74.08 | +30.92 |
| 15L | 126 | 1192.84 | 74.46 | 51.54 |
| 16L | 120 | 1456.24 | 74.80 | 45.20 |
| 17L | 114 | 1825.37 | 75.13 | 38.87 |
| 18L | 108 | 1927.04 | 75.35 | 32.65 |
| 19L | 102 | 2234.21 | 75.57 | 26.43 |
| 20L | 96 | 2636.16 | 75.79 | 20.21 |
| 21L | 90 | 2780.91 | 75.90 | 14.10 |
| 22L | 84 | 2595.52 | 75.90 | 8.10 |
| 22R | 78 | 2410.12 | 75.90 | + 2.10 |
| 21R | 72 | 2224.73 | 75.90 | - 3.90 |
| 20R | 66 | 1812.36 | 75.79 | - 9.79 |
| 19R | 60 | 1314.24 | 75.57 | -15.57 |
| 18R | 54 | 963.52 | 75.35 | -21.35 |
| 17R | 48 | 768.58 | 75.13 | 27.13 |
| 16R | 42 | 510.38 | 74.80 | 32.80 |
| 15R | 36 | 340.81 | 74.46 | 38.46 |
| 14R | 30 | 218.22 | 74.08 | 44.08 |
| 13R | 24 | 130.54 | 73.55 | 49.55 |
| 12R | 18 | 69.23 | 72.92 | 54.92 |
| 11R | 12 | 32.06 | 72.20 | 60.20 |
| 10R | 6 | 10.98 | 71.40 | 65.40 |
| 9R | 0 | 0 | 69.00 | 69.00 |
| 8R | 0 | 0 | 60.72 | 60.72 |
| 7R | 0 | 0 | 52.44 | 52.44 |
| 6R | 0 | 0 | 44.16 | 44.16 |
| 5R | 0 | 0 | 35.88 | 35.88 |
| 4R | 0 | 0 | 27.60 | 27.60 |
| 3R | 0 | 0 | 19.32 | 19.32 |
| 2R | 0 | 0 | 11.04 | -11.04 |
| 1R | 0 | 0 | -2.76 | - 2.76 |

$$\sum = 29069.66$$

$$H = \frac{29069.66}{10,547.52} = 2.76$$

LOAD = 9

| Point | INFLUENCE LOAD AT 16L | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total M |
| 1L | 0 | 0 | -3.16 | -3.16 |
| 2L | 0 | 0 | 12.64 | 12.64 |
| 3L | 0 | 0 | 22.12 | 22.12 |
| 4L | 0 | 0 | 31.60 | 31.60 |
| 5L | 0 | 0 | 41.08 | 41.08 |
| 6L | 0 | 0 | 50.56 | 50.56 |
| 7L | 0 | 0 | 60.04 | 60.04 |
| 8L | 0 | 0 | 69.52 | 69.52 |
| 9L | 0 | 0 | 79.00 | 79.00 |
| 10L | 20 | 36.60 | 81.75 | 61.75 |
| 11L | 40 | 106.88 | 82.67 | 42.67 |
| 12L | 60 | 230.76 | 83.49 | -23.49 |
| 13L | 80 | 435.12 | 84.21 | - 4.21 |
| 14L | 100 | 727.40 | 84.81 | 15.19 |
| 15L | 120 | 1136.04 | 85.26 | +34.74 |
| 16L | 140 | 1701.28 | 85.64 | 54.36 |
| 17L | 133 | 2129.60 | 86.02 | 46.98 |
| 18L | 126 | 2248.22 | 86.27 | 39.73 |
| 19L | 119 | 2606.58 | 86.52 | 32.48 |
| 20L | 112 | 3075.52 | 86.77 | 25.23 |
| 21L | 105 | 3244.40 | 86.90 | 18.10 |
| 22L | 98 | 3028.10 | 86.90 | 11.10 |
| 22R | 91 | 2811.81 | 86.90 | +4.10 |
| 21R | 84 | 2595.52 | 86.90 | -2.90 |
| 20R | 77 | 2114.42 | 86.77 | -9.77 |
| 19R | 70 | 1533.28 | 86.52 | 16.52 |
| 18R | 63 | 1124.11 | 86.27 | 23.27 |
| 17R | 56 | 896.67 | 86.02 | 30.02 |
| 16R | 49 | 595.45 | 85.64 | 36.64 |
| 15R | 42 | 397.61 | 85.26 | 43.26 |
| 14R | 35 | 254.59 | 84.81 | 49.81 |
| 13R | 28 | 152.29 | 84.21 | 56.21 |
| 12R | 21 | 80.77 | 83.49 | 62.49 |
| 11R | 14 | 37.41 | 82.67 | 68.67 |
| 10R | 7 | 12.81 | 81.75 | 74.75 |
| 9R | 0 | 0 | 79.00 | 79.00 |
| 8R | 0 | 0 | 69.52 | 69.52 |
| 7R | 0 | 0 | 60.04 | 60.04 |
| 6R | 0 | 0 | 50.56 | 50.56 |
| 5R | 0 | 0 | 41.08 | 41.08 |
| 4R | 0 | 0 | 31.60 | 31.60 |
| 3R | 0 | 0 | 22.12 | 22.12 |
| 2R | 0 | 0 | 12.64 | 12.64 |
| 1R | 0 | 0 | -3.16 | -3.16 |

$\Sigma = 33{,}313.24$

$$H = \frac{33{,}313.24}{10{,}547.52} = 3.16$$

Load = 9

| Pt. | INFLUENCE LOAD AT 17L | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total M |
| 1L | 0 | 0 | - 3.53 | - 3.53 |
| 2L | 0 | 0 | 14.12 | 14.12 |
| 3L | 0 | 0 | 24.71 | 24.71 |
| 4L | 0 | 0 | 35.30 | 35.30 |
| 5L | 0 | 0 | 45.89 | 45.89 |
| 6L | 0 | 0 | 56.48 | 56.48 |
| 7L | 0 | 0 | 67.07 | 67.07 |
| 8L | 0 | 0 | 77.66 | 77.66 |
| 9L | 0 | 0 | 88.25 | 88.25 |
| 10L | 19 | 34.77 | 91.32 | 72.32 |
| 11L | 38 | 101.54 | 92.34 | 54.34 |
| 12L | 57 | 219.22 | 93.26 | 36.26 |
| 13L | 76 | 413.36 | 94.07 | -18.07 |
| 14L | 95 | 691.03 | 94.75 | + .25 |
| 15L | 114 | 1079.24 | 95.24 | +18.76 |
| 16L | 133 | 1616.22 | 95.66 | +37.54 |
| 17L | 152 | 2433.82 | 96.09 | 55.91 |
| 18L | 144 | 2569.39 | 96.37 | 47.63 |
| 19L | 136 | 2978.94 | 96.65 | 39.35 |
| 20L | 128 | 3514.88 | 96.93 | 31.07 |
| 21L | 120 | 3707.88 | 97.08 | 22.92 |
| 22L | 112 | 3460,69 | 97.08 | 14.92 |
| 22R | 104 | 3213.50 | 97.08 | +6.92 |
| 21R | 96 | 2966.30 | 97.08 | -1.08 |
| 20R | 88 | 2416.48 | 96.93 | -8.93 |
| 19R | 80 | 1752.32 | 96.65 | 16.65 |
| 18R | 72 | 1284.70 | 96.37 | 24.36 |
| 17R | 64 | 1024.77 | 96.09 | 32.09 |
| 16R | 56 | 680.51 | 95.66 | 39.66 |
| 15R | 48 | 454.48 | 95.24 | 47.24 |
| 14R | 40 | 290.96 | 94.75 | 54.75 |
| 13R | 32 | 174.05 | 94.07 | 62.07 |
| 12R | 24 | 92.30 | 93.26 | 69.26 |
| 11R | 16 | 42.74 | 92.34 | 76.34 |
| 10R | 8 | 14.64 | 91.32 | 83.32 |
| 9R | 0 | 0 | 88.25 | 88.25 |
| 8R | 0 | 0 | 77.66 | 77.66 |
| 7R | 0 | 0 | 67.07 | 67.07 |
| 6R | 0 | 0 | 56.48 | 56.48 |
| 5R | 0 | 0 | 45.89 | 45.89 |
| 4R | 0 | 0 | 35.30 | 35.30 |
| 3R | 0 | 0 | 24.71 | 24.71 |
| 2R | 0 | 0 | 14.12 | 14.12 |
| 1R | 0 | 0 | -3.53 | -3.53 |

$\Sigma = 37{,}228.67$

$$H = \frac{37{,}228.67}{10{,}547.52} = 3.53$$

Load = 9

| Point | Mom. | $\frac{My}{I}$ | Hy | Total M |
|---|---|---|---|---|
| | | INFLUENCE LOAD AT 18 L | | |
| 1L | 0 | 0 | - 3.86 | - 3.86 |
| 2L | 0 | 0 | -15.44 | -15.44 |
| 3L | 0 | 0 | 27.02 | -27.02 |
| 4L | 0 | 0 | 38.60 | -38.60 |
| 5L | 0 | 0 | 50.18 | -50.18 |
| 6L | 0 | 0 | 61.76 | -61.76 |
| 7L | 0 | 0 | 73.34 | -73.34 |
| 8L | 0 | 0 | 84.92 | -84.92 |
| 9L | 0 | 0 | 96.50 | -96.50 |
| 10L | 18 | 32.94 | 99.86 | 81.86 |
| 11L | 36 | 96.19 | 100.98 | 64.98 |
| 12L | 54 | 207.68 | 101.98 | 47.98 |
| 13L | 72 | 391.61 | 102.87 | 30.87 |
| 14L | 90 | 654.66 | 103.60 | -13.60 |
| 15L | 108 | 1022.44 | 104.14 | + 3.86 |
| 16L | 126 | 1531.15 | 104.61 | +21.39 |
| 17L | 144 | 2305.73 | 105.07 | 38.93 |
| 18L | 162 | 2890.57 | 105.38 | 56.62 |
| 19L | 153 | 3351.31 | 105.69 | 47.31 |
| 20L | 144 | 3954.24 | 106.00 | 38.00 |
| 21L | 135 | 4171.37 | 106.15 | 28.85 |
| 22L | 126 | 3893.27 | 106.15 | 19.85 |
| 22R | 117 | 3615.18 | 106.15 | 10.85 |
| 21R | 108 | 3337.09 | 106.15 | + 1.85 |
| 20R | 99 | 2718.54 | 106.00 | - 7.00 |
| 19R | 90 | 1971.36 | 105.69 | 15.69 |
| 18R | 81 | 1445.28 | 105.38 | 24.38 |
| 17R | 72 | 1152.86 | 105.07 | 33.07 |
| 16R | 63 | 765.58 | 104.61 | 41.61 |
| 15R | 54 | 511.22 | 104.14 | 50.14 |
| 14R | 45 | 327.33 | 103.60 | 58.60 |
| 13R | 36 | 195.80 | 102.87 | 66.87 |
| 12R | 27 | 103.84 | 101.98 | 74.98 |
| 11R | 18 | 48.10 | 100.98 | 82.98 |
| 10R | 9 | 16.47 | 99.86 | 90.86 |
| 9R | 0 | 0 | 96.50 | 96.50 |
| 8R | 0 | 0 | 84.92 | 84.92 |
| 7R | 0 | 0 | 73.34 | 73.34 |
| 6R | 0 | 0 | 61.76 | 61.76 |
| 5R | 0 | 0 | 50.18 | 50.18 |
| 4R | 0 | 0 | 38.60 | 38.60 |
| 3R | 0 | 0 | 27.02 | 27.02 |
| 2R | 0 | 0 | -15.44 | 15.44 |
| 1R | 0 | 0 | - 3.86 | -3.86 |

$\sum = 40,711.81$

$$H = \frac{40,711.81}{10,547.52} = 3.86$$

Load = 9

| Point | Influence Load at 19L | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
| 1L | 0 | 0 | -4.14 | -4.14 |
| 2L | 0 | 0 | 16.56 | 16.56 |
| 3L | 0 | 0 | 28.98 | 28.98 |
| 4L | 0 | 0 | 41.40 | 41.40 |
| 5L | 0 | 0 | 53.82 | 53.82 |
| 6L | 0 | 0 | 66.24 | 66.24 |
| 7L | 0 | 0 | 78.66 | 78.66 |
| 8L | 0 | 0 | 91.08 | 91.08 |
| 9L | 0 | 0 | 103.50 | 103.50 |
| 10L | 17 | 81.11 | 107.10 | 90.10 |
| 11L | 34 | 90.85 | 108.30 | 74.30 |
| 12L | 51 | 196.15 | 109.38 | 58.38 |
| 13L | 68 | 369.85 | 110.33 | 42.33 |
| 14L | 85 | 618.29 | 111.12 | 26.12 |
| 15L | 102 | 965.63 | 111.70 | -9.70 |
| 16L | 119 | 1446.09 | 112.19 | +6.81 |
| 17L | 136 | 2177.63 | 112.69 | 23.31 |
| 18L | 153 | 2729.98 | 113.02 | 39.98 |
| 19L | 170 | 3723.66 | 113.35 | 56.65 |
| 20L | 160 | 4393.60 | 113.68 | 46.32 |
| 21L | 150 | 4634.85 | 113.85 | 36.15 |
| 22L | 140 | 4325.86 | 113.85 | 26.13 |
| 22R | 130 | 4016.87 | 113.85 | 16.15 |
| 21R | 120 | 3707.88 | 113.85 | +6.15 |
| 20R | 110 | 3020.60 | 113.68 | -3.68 |
| 19R | 100 | 2190.40 | 113.35 | 13.35 |
| 18R | 90 | 1605.87 | 113.02 | 23.02 |
| 17R | 80 | 1280.96 | 112.69 | 32.69 |
| 16R | 70 | 850.64 | 112.19 | 42.19 |
| 15R | 60 | 568.02 | 111.70 | 51.70 |
| 14R | 50 | 363.70 | 111.12 | 61.12 |
| 13R | 40 | 217.56 | 110.33 | 70.33 |
| 12R | 30 | 115.38 | 109.38 | 79.38 |
| 11R | 20 | 53.44 | 108.30 | 88.30 |
| 10R | 10 | 18.30 | 107.10 | 97.10 |
| 9R | 0 | 0 | 103.50 | 103.50 |
| 8R | 0 | 0 | 91.08 | 91.08 |
| 7R | 0 | 0 | 78.66 | 78.66 |
| 6R | 0 | 0 | 66.24 | 66.24 |
| 5R | 0 | 0 | 53.82 | 53.82 |
| 4R | 0 | 0 | 41.40 | 41.40 |
| 3R | 0 | 0 | 28.98 | 28.98 |
| 2R | 0 | 0 | 16.56 | 16.56 |
| 1R | 0 | 0 | -4.14 | -4.14 |
| | | = 43,713.19 | | |

$$H = \frac{43,713.19}{10,547.52} = 4.14$$

Load = 9

| Point | Influence Load at 20L Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
|---|---|---|---|---|
| 1L | 0 | 0 | -4.37 | -4.37 |
| 2L | 0 | 0 | 17.48 | 17.48 |
| 3L | 0 | 0 | 30.59 | 30.59 |
| 4L | 0 | 0 | 43.70 | 43.70 |
| 5L | 0 | 0 | 57.81 | 56.81 |
| 6L | 0 | 0 | 69.92 | 69.92 |
| 7L | 0 | 0 | 83.03 | 83.03 |
| 8L | 0 | 0 | 96.14 | 96.14 |
| 9L | 0 | 0 | 109.25 | 109.25 |
| 10L | 16 | 29.28 | 113.05 | 97.05 |
| 11L | 32 | 85.50 | 114.32 | 82.32 |
| 12L | 48 | 184.61 | 115.46 | 67.46 |
| 13L | 64 | 348.10 | 116.46 | 52.46 |
| 14L | 80 | 581.92 | 117.29 | 37.29 |
| 15L | 96 | 908.83 | 117.90 | 21.90 |
| 16L | 112 | 1361.02 | 118.43 | - 6.43 |
| 17L | 128 | 2049.54 | 118.95 | + 9.05 |
| 18L | 144 | 2569.39 | 119.30 | 24.70 |
| 19L | 160 | 3504.64 | 119.65 | 40.15 |
| 20L | 176 | 4832.96 | 120.00 | 56.00 |
| 21L | 165 | 5098.34 | 120.18 | 44.82 |
| 22L | 154 | 4758.45 | 120.18 | 33.82 |
| 22R | 143 | 4418.56 | 120.18 | 22.82 |
| 21R | 132 | 4078.67 | 120.18 | 11.82 |
| 20R | 121 | 3322.66 | 120.00 | +1.00 |
| 19R | 110 | 2409.44 | 119.65 | -9.65 |
| 18R | 99 | 1766.46 | 119.30 | 20.30 |
| 17R | 88 | 1409.06 | 118.95 | 30.95 |
| 16R | 77 | 935.70 | 118.43 | 41.43 |
| 15R | 66 | 624.82 | 117.90 | 51.90 |
| 14R | 55 | 400.07 | 117.29 | 62.29 |
| 13R | 44 | 239.32 | 116.46 | 72.46 |
| 12R | 33 | 126.92 | 115.46 | 82.46 |
| 11R | 22 | 58.78 | 114.32 | 92.32 |
| 10R | 11 | 20.13 | 113.05 | 102.05 |
| 9R | 0 | 0 | 109 .25 | 109.25 |
| 8R | 0 | 0 | 96.14 | 96.14 |
| 7R | 0 | 0 | 83.03 | 83.03 |
| 6R | 0 | 0 | 69.92 | 69.92 |
| 5R | 0 | 0 | 56.81 | 56.81 |
| 4R | 0 | 0 | 43.70 | 43.70 |
| 3R | 0 | 0 | 30.59 | 30.59 |
| 2R | 0 | 0 | 17.48 | 17.48 |
| 1R | 0 | 0 | -4.37 | 4.37 |
| | | = 46,123.17 | | |

$$H = \frac{46,123.17}{10,547.52} = 4.37$$

Load = 9

| Point | Influence Load at 21L | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
| 1L | 0 | 0 | -4.53 | -4.53 |
| 2L | 0 | 0 | 18.12 | 18.12 |
| 3L | 0 | 0 | 31.71 | 31.71 |
| 4L | 0 | 0 | 45.30 | 45.30 |
| 5L | 0 | 0 | 58.89 | 58.89 |
| 6L | 0 | 0 | 72.48 | 72.48 |
| 7L | 0 | 0 | 86.07 | 86.07 |
| 8L | 0 | 0 | 99.66 | 99.66 |
| 9L | 0 | 0 | 113.25 | 113.25 |
| 10L | 15 | 27.45 | 117.19 | 102.19 |
| 11L | 30 | 80.16 | 118.50 | 88.50 |
| 12L | 45 | 173.07 | 119.68 | 74.68 |
| 13L | 60 | 326.34 | 120.72 | 60.72 |
| 14L | 75 | 545.55 | 121.59 | 46.59 |
| 15L | 90 | 852.03 | 122.22 | 32.22 |
| 16L | 105 | 1275.96 | 122.76 | 17.76 |
| 17L | 120 | 1921.44 | 123.31 | -3.31 |
| 18L | 135 | 2408.81 | 123.67 | +11.33 |
| 19L | 150 | 3285.60 | 124.03 | 25.97 |
| 20L | 165 | 4530.90 | 124.39 | 40.61 |
| 21L | 180 | 5561.82 | 124.58 | 55.42 |
| 22L | 168 | 5191.03 | 124.58 | 43.42 |
| 22R | 156 | 4820.24 | 124.58 | 31.42 |
| 21R | 144 | 4449.46 | 124.58 | 19.42 |
| 20R | 132 | 3624.72 | 124.39 | +7.61 |
| 19R | 120 | 2628.48 | 124.03 | -4.03 |
| 18R | 108 | 1927.04 | 123.67 | 15.67 |
| 17R | 96 | 1537.15 | 123.31 | 27.31 |
| 16R | 84 | 1020.77 | 122.76 | 38.76 |
| 15R | 72 | 681.62 | 122.22 | 50.22 |
| 14R | 60 | 436.44 | 121.59 | 61.59 |
| 13R | 48 | 261.07 | 120.72 | 72.72 |
| 12R | 36 | 138.46 | 119.68 | 83.68 |
| 11R | 24 | 64.13 | 118.50 | 94.50 |
| 10R | 12 | 21.96 | 117.19 | 105.19 |
| 9R | 0 | 0 | 113.25 | 113.25 |
| 8R | 0 | 0 | 99.66 | 99.66 |
| 7R | 0 | 0 | 86.07 | 86.07 |
| 6R | 0 | 0 | 72.48 | 72.48 |
| 5R | 0 | 0 | 58.89 | 58.89 |
| 4R | 0 | 0 | 45.30 | 45.30 |
| 3R | 0 | 0 | 31.71 | 31.71 |
| 2R | 0 | 0 | 18.12 | 18.12 |
| 1R | 0 | 0 | - 4.53 | -4.53 |

= 47,791.70

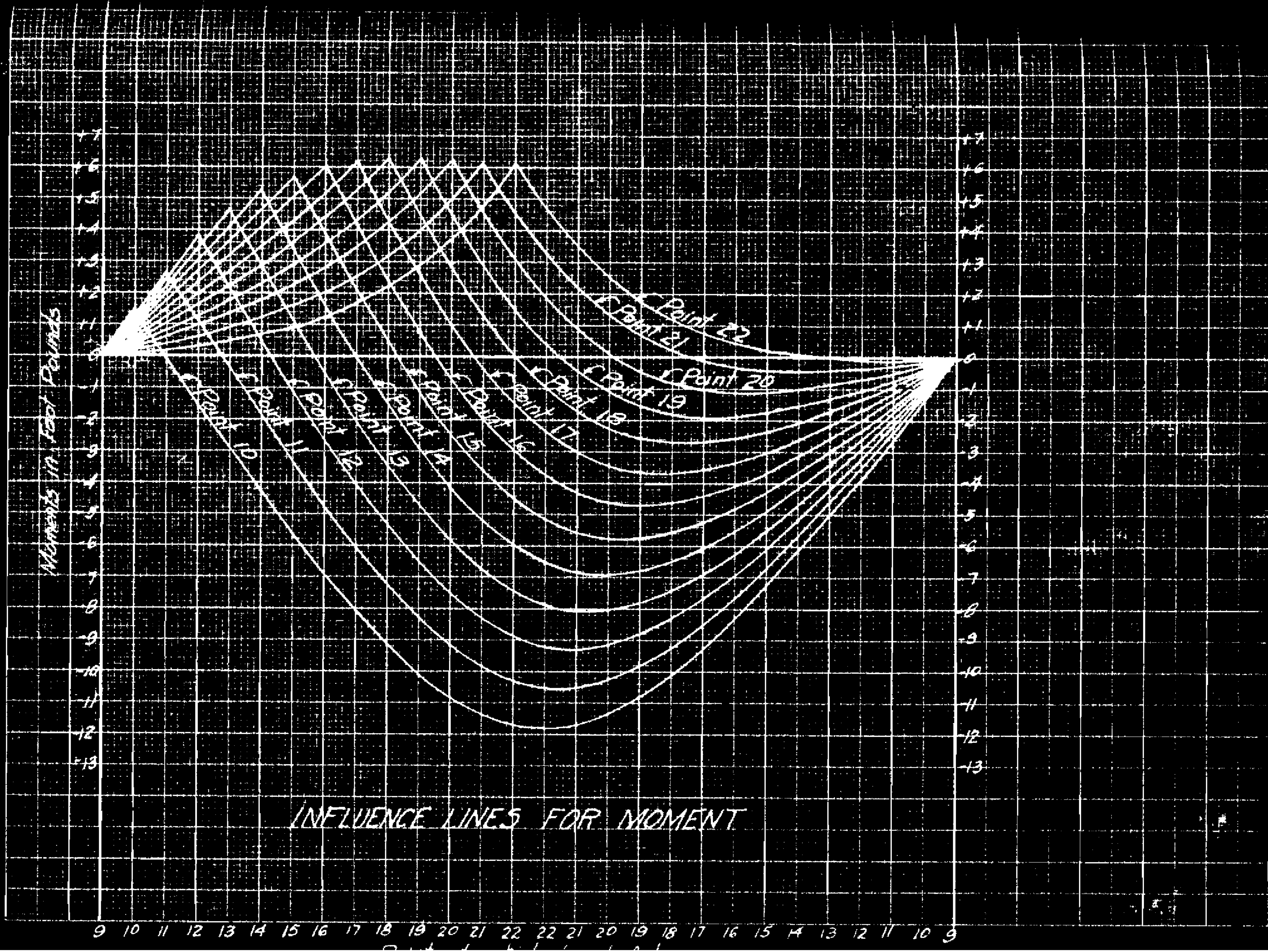
$$H = \frac{47{,}791.70}{10{,}547.52} = 4.53$$

Load = 9

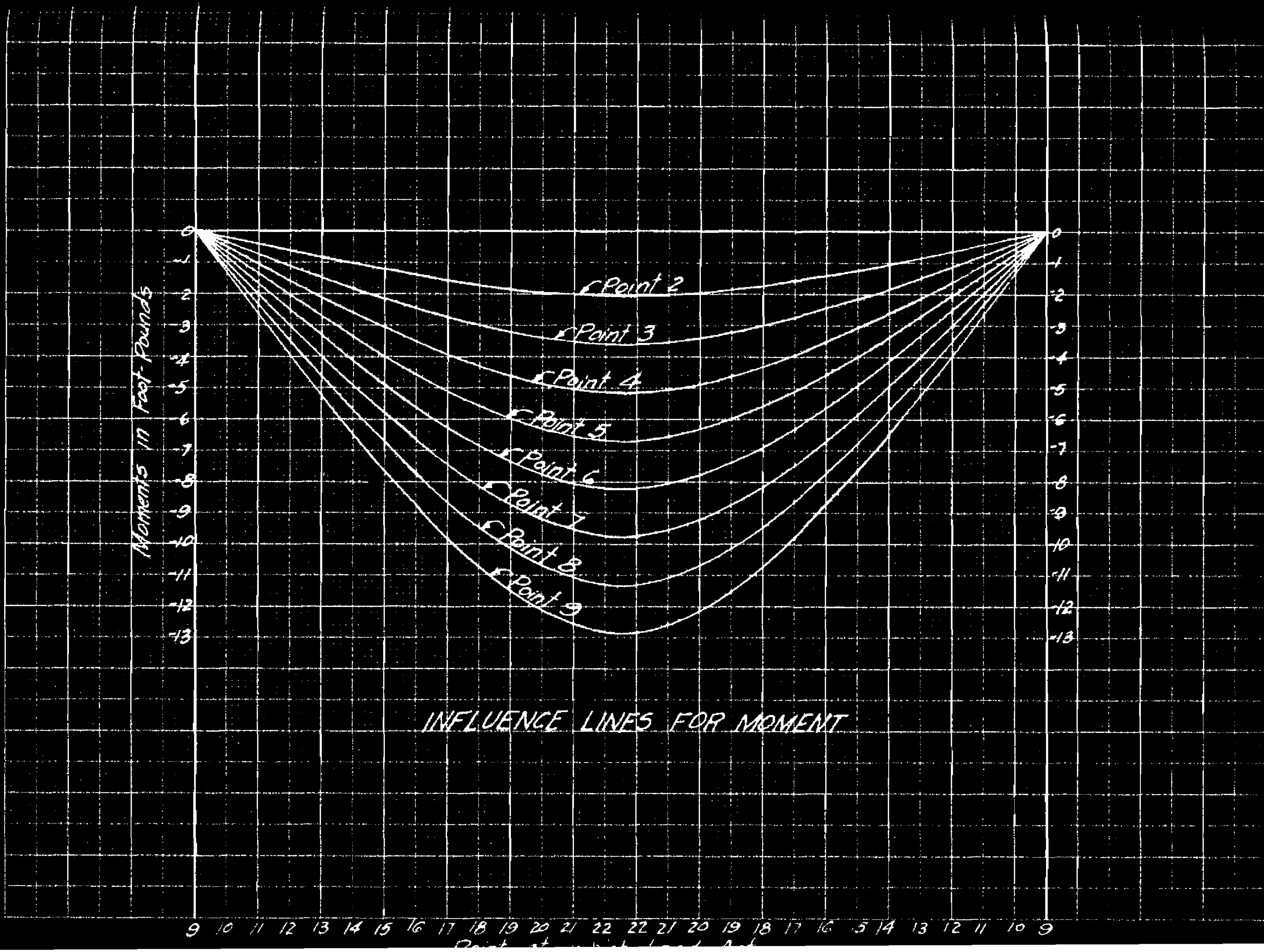
| Point | Influence Load at 22L Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
|---|---|---|---|---|
| 1L | 0 | 0 | -4.61 | -4.61 |
| 2L | 0 | 0 | 18.44 | 18.44 |
| 3L | 0 | 0 | 32.27 | 32.27 |
| 4L | 0 | 0 | 46.10 | 46.10 |
| 5L | 0 | 0 | 59.93 | 59.93 |
| 6L | 0 | 0 | 73.76 | 73.76 |
| 7L | 0 | 0 | 87.59 | 87.59 |
| 8L | 0 | 0 | 101.42 | 101.42 |
| 9L | 0 | 0 | 115.25 | 115.25 |
| 10L | 14 | 25.62 | 119.26 | 105.26 |
| 11L | 28 | 74.62 | 120.60 | 92.60 |
| 12L | 42 | 161.53 | 121.80 | 79.80 |
| 13L | 56 | 304.58 | 122.86 | 66.86 |
| 14L | 70 | 509.18 | 123.73 | 53.73 |
| 15L | 84 | 795.23 | 124.38 | 40.38 |
| 16L | 98 | 1190.90 | 124.95 | 26.93 |
| 17L | 112 | 1793.34 | 125.48 | -13.48 |
| 18L | 126 | 2248.22 | 125.85 | ≠ .15 |
| 19L | 140 | 3066.56 | 126.22 | 13.78 |
| 20L | 154 | 4228.84 | 126.59 | 27.41 |
| 21L | 168 | 5191.05 | 126.78 | 41.22 |
| 22L | 182 | 5623.62 | 126.78 | 55.22 |
| 22R | 169 | 5221.93 | 126.78 | 42.22 |
| 21R | 156 | 4820.24 | 126.78 | 29.22 |
| 20R | 143 | 3926.78 | 126.59 | 16.41 |
| 19R | 130 | 2847.52 | 126.22 | ≠ 3.78 |
| 18R | 117 | 2087.63 | 125.85 | - 8.85 |
| 17R | 104 | 1665.25 | 125.48 | 21.48 |
| 16R | 91 | 1105.83 | 124.93 | 33.93 |
| 15R | 78 | 738.43 | 124.38 | 46.38 |
| 14R | 65 | 472.81 | 123.73 | 58.73 |
| 13R | 52 | 282.83 | 122.86 | 70.86 |
| 12R | 39 | 149.99 | 121.80 | 82.80 |
| 11R | 26 | 69.47 | 120.60 | 94.60 |
| 10R | 13 | 23.79 | 119.26 | 106.26 |
| 9R | 0 | 0 | 115.25 | 115.25 |
| 8R | 0 | 0 | 101.42 | 101.42 |
| 7R | 0 | 0 | 87.59 | 87.59 |
| 6R | 0 | 0 | 73.76 | 73.76 |
| 5R | 0 | 0 | 59.93 | 59.93 |
| 4R | 0 | 0 | 46.10 | 46.10 |
| 3R | 0 | 0 | 32.27 | 32.27 |
| 2R | 0 | 0 | 18.44 | 18.44 |
| 1R | 0 | 0 | -4.61 | -4.61 |

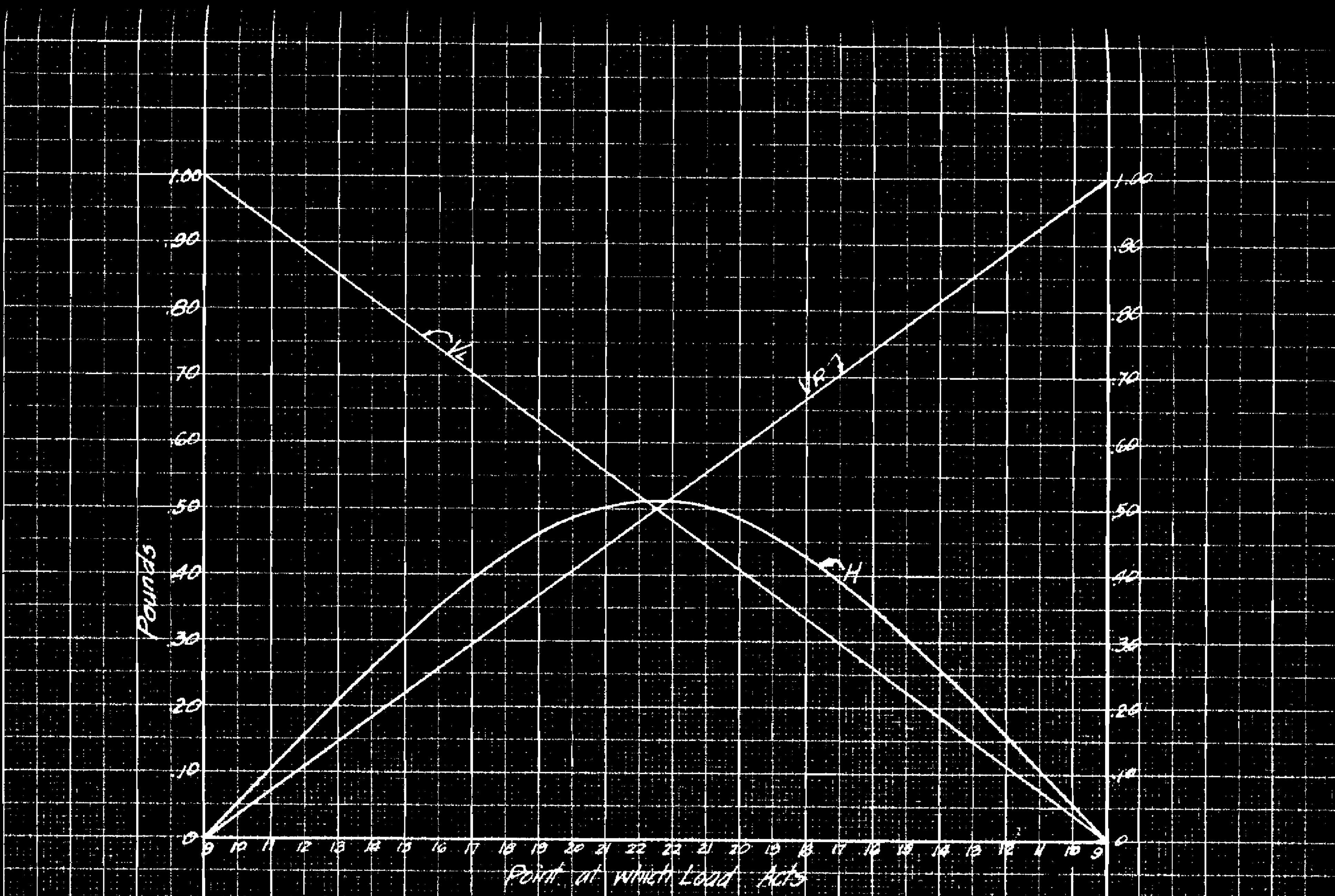
= 48,625.97

$$H = \frac{48,625.97}{10,547.52} = 4.61$$



INFLUENCE LINES FOR MOMENT
Moments in Foot Pounds
℄ Point 10
℄ Point 11
℄ Point 12
℄ Point 13
℄ Point 14
℄ Point 15
℄ Point 16
℄ Point 17
℄ Point 18
℄ Point 19
℄ Point 20
℄ Point 21
℄ Point 22
+7
+6
+5
+4
+3
+2
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
9 10 11 12 13 14 15 16 17 18 19 20 21 22 22 21 20 19 18 17 16 15 14 13 12 11 10 9


INFLUENCE LINES FOR MOMENT
Moments in Foot Pounds
Point 2
Point 3
Point 4
Point 5
Point 6
Point 7
Point 8
Point 9
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
9 10 11 12 13 14 15 16 17 18 19 20 21 22 22 21 20 19 18 17 16 15 14 13 12 11 10 9




INFLUENCE LINES FOR REACTIONS

CALCULATION OF DEAD LOAD AT VARIOUS POINTS.

Concrete is assumed to weigh 150 lbs. per cu. ft.
4" concrete paving is assumed, weighing 50 lbs. per sq. ft.

Pt. 22
Rib - (2.0x1.0x3.0)x150 = 900#
Paving - 3,0x50 = 150#
1050#

Pt. 21
Same as Pt. 22 = 1050#

Pt. 20
Rib- (2.08x1.0x3.0)x150 = 936#
Paving - 150#
1086#

Pt. 19
Rib (2.26x1.0x3.0)x150 = 1017#
Paving 150
1167#

Pt. 18
Rib (2.42x1.0x3.0)x150 = 1090#
Paving - 150
1240#

Pt. 17
Rib (2.58x1.0x3.0)x150 = 1161#
Paving - 150#
1311#

Pt. 16
Rib (2.83x1.0x3.0)x150 = 1273#
Paving- 150
1423#

Pt. 15
Rib (3.08x1.0x3.0)x150 = 1387#
Paving- 150#
1537#

Pt. 14
Rib (3.37x1.0x3.0)x150 = 1518#
Paving - 150#
1668#

Pt. 13
Rib (3.75x1.0x3.0)x150 = 1688#
Paving- 150#
1838#

Pt. 12
Rib (4.21x1.0x3.0)x150 = 1892#
Paving 150#
2042#

Pt. 11
Rib (4.75x1.0x3.0)x150 = 2138#
Paving - 150#
2288#

Calculation of Dead Loads - Cont'd.

Pt. 10

Rib (5.33x1.0x3.0) 150 = 2400#
Paving 150#
2550#

Pt. 9

Knee (5.0x5.0x1.0) 150 = 3750#
Paving 2.25x50 113
3863

Pt. 8

Leg. (5.69x1.0x3.0)150 = 2560#

Pt. 7

(5.35x1.0x3.0)150 = 2405#

Pt. 6

(5.02x1.0x3.0)150 = 2260#

Pt. 5

(4.69x1.0x3.0)150 = 2110#

Pt. 4

(4.33x1.0x3.0)150 = 1950#

Pt. 3

(4.00x1.0x3.0)150 = 1800#

Pt. 2

(3.67x1.0x3.0)150 = 1650#

Pt. 1

(2.0x2.0x1.0)+ (2.0x9.0x1.0)

+ (2.5x1.0x3.67) 150 = 4680#

DEAD LOAD MOMENT FACTORS AND MOMENTS

| Ld. at Pt. | Ld. | Point 2 MF | Point 2 M | Point 3 MF | Point 3 M | Point 4 MF | Point 4 M | Point 5 MF | Point 5 M | Point 6 MF | Point 6 M | Load at Point |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10L | 2550 | .21 | -536 | .38 | - 970 | .53 | -1352 | .70 | -1785 | .83 | -2115 | 10L |
| 11L | 2288 | .42 | 962 | .75 | 1717 | 1.04 | 2381 | 1.38 | 3160 | 1.65 | 3780 | 11L |
| 12L | 2042 | .62 | 1267 | 1.12 | 2286 | 1.59 | 3245 | 2.07 | 4225 | 2.52 | 5140 | 12L |
| 13L | 1838 | .82 | 1508 | 1.47 | 2720 | 2.12 | 3900 | 2.71 | 4980 | 3.33 | 6120 | 13L |
| 14L | 1668 | 1.01 | 1685 | 1.82 | 3038 | 2.60 | 4340 | 3.37 | 5625 | 4.15 | 6920 | 14L |
| 15L | 1537 | 1.21 | 1860 | 2.15 | 3304 | 3.05 | 4690 | 4.00 | 6150 | 4.92 | 7565 | 15L |
| 16L | 1423 | 1.41 | 2008 | 2.47 | 3520 | 3.52 | 5010 | 4.56 | 6490 | 5.61 | 7990 | 16L |
| 17L | 1311 | 1.57 | 2059 | 2.72 | 3566 | 3.89 | 5100 | 5.10 | 6685 | 6.28 | 8230 | 17L |
| 18L | 1240 | 1.65 | 2045 | 3.00 | 3720 | 4.30 | 5333 | 5.56 | 6890 | 6.87 | 8520 | 18L |
| 19L | 1167 | 1.80 | 2100 | 3.25 | 3790 | 4.61 | 5375 | 6.00 | 7000 | 7.37 | 8600 | 19L |
| 20L | 1086 | 1.93 | 2095 | 3.40 | 3690 | 4.82 | 5235 | 6.32 | 6860 | 7.75 | 8410 | 20L |
| 21L | 1050 | 2.02 | 2121 | 3.50 | 3675 | 5.03 | 5280 | 6.54 | 6870 | 8.07 | 8480 | 21L |
| 22L | 1050 | 2.04 | 2142 | 3.58 | 3760 | 5.14 | 5400 | 6.66 | 6990 | 8.20 | 8610 | 22L |
| 22R | 1050 | 2.04 | 2142 | 3.58 | 3760 | 5.14 | 5400 | 6.66 | 6990 | 8.20 | 8610 | 22R |
| 21R | 1050 | 2.02 | 2121 | 3.50 | 3675 | 5.03 | 5280 | 6.54 | 6870 | 8.07 | 8480 | 21R |
| 20R | 1086 | 1.93 | 2095 | 3.40 | 3690 | 4.82 | 5235 | 6.32 | 6860 | 7.75 | 8410 | 20R |
| 19R | 1167 | 1.80 | 2100 | 3.25 | 3790 | 4.61 | 5375 | 6.00 | 7000 | 7.37 | 8600 | 19R |
| 18R | 1240 | 1.65 | 2045 | 3.00 | 3720 | 4.30 | 5333 | 5.56 | 6890 | 6.87 | 8520 | 18R |
| 17R | 1311 | 1.57 | 2059 | 2.72 | 3566 | 3.89 | 5100 | 5.10 | 6685 | 6.28 | 8230 | 17R |
| 16R | 1423 | 1.41 | 2008 | 2.47 | 3520 | 3.52 | 5010 | 4.56 | 6490 | 5.61 | 7990 | 16R |
| 15R | 1537 | 1.21 | 1860 | 2.15 | 3304 | 3.05 | 4690 | 4.00 | 6150 | 4.92 | 7565 | 15R |
| 14R | 1668 | 1.01 | 1685 | 1.82 | 3038 | 2.60 | 4340 | 3.37 | 5625 | 4.15 | 6920 | 14R |
| 13R | 1838 | .82 | 1508 | 1.47 | 2720 | 2.12 | 3900 | 2.71 | 4980 | 3.33 | 6120 | 13R |
| 12R | 2042 | .62 | 1267 | 1.12 | 2286 | 1.59 | 3245 | 2.07 | 4225 | 2.52 | 5140 | 12R |
| 11R | 2288 | .42 | 962 | .75 | 1717 | 1.04 | 2381 | 1.38 | 3160 | 1.65 | 3780 | 11R |
| 10R | 2550 | .21 | -536 | .38 | -970 | .53 | -1352 | .70 | -1785 | .83 | -2115 | 10R |
| Totals | | | -43,776 | | -79,512 | | -113,282 | | -147,420 | | -180,960 | |

| Load at Pt. | Load | Point 7 MF | Point 7 M | Point 8 MF | Point 8 M | Point 9 MF | Point 9 M | Point 10 MF | Point 10 M | Point 11 MF | Point 11 M | Load at Pt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10L | 2550 | -1.02 | -2600 | -1.19 | -3035 | -1.35 | - 3440 | +1.50 | +3821 | +1.38 | +3519 | 10L |
| 11L | 2288 | 2.03 | 4650 | 2.36 | 5410 | 2.66 | 6090 | .00 | | 2.65 | 6020 | 11L |
| 12L | 2042 | 3.02 | 6165 | 3.50 | 7150 | 4.00 | 8170 | -1.55 | -3163 | +1.15 | +2350 | 12L |
| 13L | 1838 | 4.00 | 7355 | 4.62 | 8490 | 5.24 | 9645 | -2.85 | 5240 | - .35 | - 644 | 13L |
| 14L | 1668 | 4.92 | 8210 | 5.70 | 9520 | 6.50 | 10840 | 4.27 | 7130 | -1.88 | 3135 | 14L |
| 15L | 1537 | 5.80 | 8920 | 6.73 | 10330 | 7.65 | 11750 | 5.60 | 8605 | 3.37 | 5180 | 15L |
| 16L | 1423 | 6.67 | 9500 | 7.70 | 10970 | 8.75 | 12450 | 6.86 | 9770 | 4.75 | 6760 | 16L |
| 17L | 1311 | 7.45 | 9760 | 8.63 | 11400 | 9.82 | 12970 | 8.07 | 10580 | 6.08 | 7965 | 17L |
| 18L | 1240 | 8.18 | 10150 | 9.45 | 11720 | 10.73 | 13320 | 9.15 | 11350 | 7.25 | 8990 | 18L |
| 19L | 1167 | 8.73 | 10180 | 10.12 | 11800 | 11.50 | 13420 | 1010 | 11780 | 8.25 | 9625 | 19L |
| 20L | 1086 | 9.23 | 10020 | 10.70 | 11620 | 12.12 | 13150 | 10.81 | 11730 | 9.15 | 9935 | 20L |
| 21L | 1050 | 9.56 | 10030 | 11.08 | 11620 | 12.55 | 13180 | 11.37 | 11930 | 9.85 | 10235 | 21L |
| 22L | 1050 | 9.75 | 10230 | 11.30 | 11870 | 12.80 | 13430 | 11.70 | 12280 | 10.30 | 10820 | 22L |
| 22R | 1050 | 9.75 | 10230 | 11.30 | 11870 | 12.80 | 13430 | 11.80 | 12380 | 10.50 | 11020 | 22R |
| 21R | 1050 | 9.56 | 10030 | 11.08 | 11620 | 12.55 | 13180 | 11.70 | 12280 | 10.50 | 11020 | 21R |
| 20R | 1086 | 9.23 | 10020 | 10.70 | 11620 | 12.12 | 13150 | 11.38 | 12360 | 10.27 | 11130 | 20R |
| 19R | 1167 | 8.73 | 10180 | 10.12 | 11800 | 11.50 | 13420 | 10.80 | 12590 | 9.81 | 11425 | 19R |
| 18R | 1240 | 8.18 | 10150 | 9.45 | 11720 | 10.73 | 13320 | 10.13 | 12580 | 9.23 | 11430 | 18R |
| 17R | 1311 | 7.45 | 9760 | 8.63 | 11400 | 9.82 | 12970 | 9.30 | 12190 | 8.50 | 11130 | 17R |
| 16R | 1423 | 6.67 | 9500 | 7.70 | 10970 | 8.75 | 12450 | 8.30 | 11820 | 7.63 | 10870 | 16R |
| 15R | 1537 | 5.80 | 8920 | 6.73 | 10330 | 7.65 | 11750 | 7.26 | 11180 | 6.72 | 10320 | 15R |
| 14R | 1668 | 4.92 | 8210 | 5.70 | 9520 | 6.50 | 10840 | 6.15 | 10270 | 5.68 | 9460 | 14R |
| 13R | 1838 | 4.00 | 7355 | 4.62 | 8490 | 5.24 | 9645 | 4.99 | 9190 | 4.58 | 8420 | 13R |
| 12R | 2042 | 3.02 | 6165 | 3.50 | 7150 | 4.00 | 8170 | 3.90 | 7965 | 3.52 | 7190 | 12R |
| 11R | 2288 | 2.03 | 4650 | 2.36 | 5410 | 2.66 | 6090 | 2.70 | 4450 | 2.40 | 5490 | 11R |
| 10R | 2550 | -1.02 | -2600 | -1.19 | -3035 | -1.35 | -3440 | 1.35 | -2600 | 1.20 | -3061 | 10R |
| Totals- | | | -215,540 | | -249,870 | | -283,710 | | -231,592 | | - 183,316 | |

| Load at Pt. | Load | Point 12 MF | Point 12 M | Point 13 MF | Point 13 M | Point 14 MF | Point 14 M | Point 15 MF | Point 15 M | Point 16 MF | Point 16 M | Load at Point |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10L | 2550 | +1.25 | +3188 | +1.12 | +2857 | +.98 | +2498 | + .88 | +2242 | +.77 | +1963 | 10L |
| 11L | 2288 | 2.50 | 5725 | 2.25 | 5150 | 2.02 | 4625 | 1.77 | 4055 | 1.55 | 3544 | 11L |
| 12L | 2042 | 3.92 | 8010 | 3.43 | 6805 | 3.05 | 6250 | 2.70 | 5515 | 2.38 | 4860 | 12L |
| 13L | 1838 | 2.18 | 4010 | 4.65 | 8550 | 4.15 | 7635 | 3.68 | 6765 | 3.23 | 5940 | 13L |
| 14L | 1668 | +.50 | +834 | 2.87 | 4790 | 5.27 | 8800 | 4.65 | 7760 | 4.12 | 6885 | 14L |
| 15L | 1537 | -1.10 | -1690 | +1.15 | +1768 | 3.42 | 5260 | 5.70 | 8760 | 5.05 | 7760 | 15L |
| 16L | 1423 | 2.64 | 3760 | -.50 | - 711 | +1.70 | +2420 | 3.86 | 5495 | 6.05 | 8615 | 16L |
| 17L | 1311 | 4.08 | 5340 | 2.00 | 2622 | .00 | - | 2.08 | 2725 | 4.17 | 5465 | 17L |
| 18L | 1240 | 5.32 | 6600 | 3.43 | 4255 | -1.50 | -1860 | + .44 | +545 | 2.40 | 2978 | 18L |
| 19L | 1167 | 6.50 | 7580 | 4.70 | 5485 | 2.90 | 3381 | -1.12 | -1307 | +.80 | +933 | 19L |
| 20L | 1086 | 7.48 | 8115 | 5.82 | 6320 | 4.18 | 4540 | 2.45 | 2666 | -.73 | -793 | 20L |
| 21L | 1050 | 8.32 | 8735 | 6.75 | 7090 | 5.20 | 5460 | 3.58 | 3760 | 2.00 | 2100 | 21L |
| 22L | 1050 | 8.85 | 9290 | 7.40 | 7765 | 6.00 | 6300 | 4.50 | 4725 | 3.00 | 3150 | 22L |
| 22R | 1050 | 9.20 | 9660 | 7.82 | 8210 | 6.54 | 6870 | 5.18 | 5440 | 3.78 | 3970 | 22R |
| 21R | 1050 | 9.30 | 9765 | 8.07 | 8470 | 6.85 | 7190 | 5.59 | 5870 | 4.32 | 4540 | 21R |
| 20R | 1086 | 9.17 | 9960 | 8.05 | 8740 | 6.90 | 7495 | 5.78 | 6270 | 4.61 | 5000 | 20R |
| 19R | 1167 | 8.82 | 10280 | 7.80 | 9100 | 6.80 | 7935 | 5.75 | 6710 | 4.66 | 5435 | 19R |
| 18R | 1240 | 8.33 | 10325 | 7.42 | 9200 | 6.50 | 8060 | 5.58 | 6918 | 4.61 | 5713 | 18R |
| 17R | 1311 | 7.70 | 10090 | 6.93 | 9085 | 6.12 | 8025 | 5.25 | 6885 | 4.42 | 5790 | 17R |
| 16R | 1423 | 6.95 | 9900 | 6.25 | 8900 | 5.50 | 7835 | 4.82 | 6865 | 4.08 | 5810 | 16R |
| 15R | 1537 | 6.08 | 9350 | 5.50 | 8455 | 4.93 | 7575 | 4.27 | 6565 | 3.64 | 5596 | 15R |
| 14R | 1668 | 5.18 | 8650 | 4.70 | 7840 | 4.18 | 6970 | 3.66 | 6110 | 3.15 | 5255 | 14R |
| 13R | 1838 | 4.20 | 7720 | 3.78 | 6950 | 3.42 | 6290 | 2.98 | 5480 | 2.58 | 4745 | 13R |
| 12R | 2042 | 3.22 | 6580 | 2.92 | 5965 | 2.62 | 5360 | 2.33 | 4760 | 1.98 | 4040 | 12R |
| 11R | 2288 | 2.18 | 4980 | 2.00 | 4576 | 1.75 | 4005 | 1.55 | 3550 | 1.33 | 3044 | 11R |
| 10R | 2550 | -1.08 | -2755 | -1.00 | -2550 | -.88 | - 2242 | -.79 | -2015 | -.68 | -1733 | 10R |
| Totals - | | | -139,358 | | -102,369 | | -69,925 | | -42,034 | | -19,770 | |

| Load at Pt. | Load | Point 17 MF | Point 17 M | Point 18 MF | Point 18 M | Point 19 MF | Point 19 M | Point 20 MF | Point 20 M | Point 21 MF | Point 21 M | Load at Point |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10L | 2550 | + .63 | +1607 | + .51 | + 1301 | + .41 | +1047 | + .30 | + 768 | + .19 | +485 | 10L |
| 11L | 2288 | 1.27 | 2907 | 1.05 | 2405 | .83 | 1900 | .63 | 1442 | .40 | 916 | 11L |
| 12L | 2042 | 2.00 | 4084 | 1.65 | 3370 | 1.27 | 2595 | .98 | 2001 | .62 | 1267 | 12L |
| 13L | 1838 | 2.70 | 4965 | 2.28 | 4190 | 1.78 | 3275 | 1.38 | 2539 | .90 | 1653 | 13L |
| 14L | 1668 | 3.50 | 5840 | 2.85 | 4760 | 2.33 | 3890 | 1.78 | 2970 | 1.23 | 2053 | 14L |
| 15L | 1537 | 4.28 | 6580 | 3.64 | 5600 | 2.90 | 4460 | 2.27 | 3490 | 1.58 | 2430 | 15L |
| 16L | 1423 | 5.20 | 7400 | 4.42 | 6290 | 3.60 | 5125 | 2.80 | 3985 | 2.00 | 2846 | 16L |
| 17L | 1311 | 6.19 | 8115 | 5.27 | 6910 | 4.35 | 5700 | 3.45 | 4520 | 2.53 | 3315 | 17L |
| 18L | 1240 | 4.25 | 5270 | 6.28 | 7790 | 5.22 | 6480 | 4.25 | 5270 | 3.12 | 3870 | 18L |
| 19L | 1167 | 2.57 | 2995 | 4.45 | 5190 | 6.27 | 7310 | 5.20 | 6060 | 4.00 | 4665 | 19L |
| 20L | 1086 | +.98 | +1063 | 2.78 | 3017 | 4.48 | 4870 | 6.23 | 6760 | 5.00 | 5430 | 20L |
| 21L | 1050 | -.38 | - 399 | +1.25 | +1312 | 2.90 | 3043 | 4.50 | 4725 | 6.17 | 6480 | 21L |
| 22L | 1050 | 1.50 | 1575 | .00 | - | 1.50 | 1575 | 3.05 | 3200 | 4.59 | 4820 | 22L |
| 22R | 1050 | 2.40 | 2520 | -1.00 | -1050 | + .41 | +431 | 1.82 | 1900 | 3.27 | 3430 | 22R |
| 21R | 1050 | 3.04 | 3193 | 1.75 | 1838 | - .48 | -504 | .87 | 913 | 2.17 | 2280 | 21R |
| 20R | 1086 | 3.47 | 3765 | 2.28 | 2475 | 1.08 | 1172 | + .14 | + 152 | 1.33 | 1443 | 20R |
| 19R | 1167 | 3.65 | 4255 | 2.58 | 3010 | 1.53 | 1784 | - .45 | - 525 | .70 | 816 | 19R |
| 18R | 1240 | 3.70 | 4590 | 2.70 | 3350 | 1.78 | 2207 | .77 | 955 | + .22 | +273 | 18R |
| 17R | 1311 | 3.55 | 4650 | 2.70 | 3540 | 1.90 | 2490 | 1.00 | 1311 | - .10 | -131 | 17R |
| 16R | 1423 | 3.35 | 4765 | 2.60 | 3700 | 1.90 | 2705 | 1.12 | 1594 | .30 | 427 | 16R |
| 15R | 1537 | 3.06 | 4710 | 2.38 | 3660 | 1.77 | 2720 | 1.14 | 1753 | .42 | 646 | 15R |
| 14R | 1668 | 2.62 | 4370 | 2.07 | 3455 | 1.54 | 2570 | 1.00 | 1668 | .42 | 701 | 14R |
| 13R | 1838 | 2.15 | 3955 | 1.72 | 3162 | 1.32 | 2425 | .84 | 1543 | .40 | 736 | 13R |
| 12R | 2042 | 1.68 | 3430 | 1.33 | 2717 | 1.06 | 2165 | .69 | 1410 | .37 | 756 | 12R |
| 11R | 2288 | 1.16 | 2658 | .92 | 2106 | .75 | 1718 | .53 | 1213 | .28 | 641 | 11R |
| 10R | 2550 | -.58 | -1480 | .46 | - 1173 | .38 | -970 | .27 | -689 | - .14 | -357 | 10R |
| Totals | | | +1511 | | +16,899 | | +28,271 | | +36,032 | | +44,077 | |

| Load At Point | Load | Point 22 | |
|---|---|---|---|
| | | MF | M |
| 10L | 2550 | + .09 | + 230 |
| 11L | 2288 | .19 | 435 |
| 12L | 2042 | .32 | 654 |
| 13L | 1838 | .50 | 919 |
| 14L | 1668 | .67 | 1117 |
| 15L | 1537 | .86 | 1322 |
| 16L | 1423 | 1.23 | 1750 |
| 17L | 1311 | 1.66 | 2175 |
| 18L | 1240 | 2.20 | 2730 |
| 19L | 1167 | 2.90 | 3380 |
| 20L | 1086 | 3.72 | 4040 |
| 21L | 1050 | 4.80 | 5040 |
| 22L | 1050 | 6.13 | 6435 |
| 22R | 1050 | 4.70 | 4935 |
| 21R | 1050 | 3.48 | 3655 |
| 20R | 1086 | 2.52 | 2717 |
| 19R | 1167 | 1.78 | 2075 |
| 18R | 1240 | 1.20 | 1488 |
| 17R | 1311 | .78 | 1022 |
| 16R | 1423 | .46 | 655 |
| 15R | 1537 | .25 | 385 |
| 14R | 1668 | + .10 | + 167 |
| 13R | 1838 | 0 | - |
| 12R | 2042 | - .07 | - 143 |
| 11R | 2288 | .10 | 229 |
| 10R | 2550 | - .05 | - 128 |

+ 46,826

Components of Reactions Due to Dead Load.

$V_l = V_r = 43,528\#$

| Load at Point | D.L. | HF | H |
|---|---|---|---|
| 10 | 2550 | .055 | 135 |
| 11 | 2288 | .106 | 243 |
| 12 | 2042 | .158 | 323 |
| 13 | 1838 | .209 | 384 |
| 14 | 1668 | .258 | 431 |
| 15 | 1537 | .307 | 472 |
| 16 | 1425 | .351 | 500 |
| 17 | 1311 | .391 | 512 |
| 18 | 1240 | .430 | 534 |
| 19 | 1167 | .460 | 536 |
| 20 | 1086 | .485 | 526 |
| 21 | 1050 | .505 | 530 |
| 22 | 1050 | .511 | 536 |

5662 x 2 = 11,334#

---

NORMAL THRUSTS DUE TO DEAD LOAD

Point 1

N = V = 43,528 #

Point 2

N = 43,528 - 4680 = 38,848#

Point 3

N = 38,848 -1650 = 37,198#

Point 4

N = 37,198 -1800 = 35,398#

Point 5

N = 35,398 -1950 = 33,448#

Point 6

N = 33,448 -2110 = 31,338#

Point 7

N = 31,338-2260 = 29,078#

Point 8

N = 29,078-2405 = 27,673#

Point 9

N = (27,673-2560) .71+(11,334x.71)= 25,850#

(Since components of H and V at $45^{\circ}$ make up N)

Points 10-22

N = H = 11,334#

TEMPERATURE STRESSES

C = .0000065

t = +50 or -30

l = 81

E = Modulus of elasticity of concrete = 144x2,000,000=288,000,000 lbs./sq.in.

S = 3 ft.

$$H = \frac{Etl}{S\sum\frac{y^2}{I}}$$

$$H = +\frac{288,000,000 \times .0000065 \times 50 \times 81}{3 \times 10,547.52} = +238$$

$$H = -\frac{288,000,000 \times .0000065 \times 30 \times 81}{3 \times 10,547.52} = -144$$

| Point | Y | -Hy | +Hy |
|---|---|---|---|
| 2 | 4.0 | -953 | +576 |
| 3 | 7.0 | -1665 | +1008 |
| 4 | 10.0 | -2380 | +1440 |
| 5 | 13.0 | -3095 | +1873 |
| 6 | 16.0 | -3810 | +2305 |
| 7 | 19.0 | -4525 | +2735 |
| 8 | 22.0 | -5240 | +3170 |
| 9 | 25.0 | -5960 | +3600 |
| 10 | 25.87 | -6160 | +3730 |
| 11 | 26.16 | -6230 | +3762 |
| 12 | 26.42 | -6290 | +3810 |
| 13 | 26.65 | -6350 | +3840 |
| 14 | 26.84 | -6400 | +3867 |
| 15 | 26.98 | -6425 | +3885 |
| 16 | 27.10 | -6450 | +3905 |
| 17 | 27.22 | -6490 | +3920 |
| 18 | 27.30 | -6510 | +3935 |
| 19 | 27.38 | -6520 | +3942 |
| 20 | 27.46 | -6540 | +3958 |
| 21 | 27.50 | -6550 | +3962 |
| 22 | 27.50 | -6550 | +3962 |

Points 2 to 8 N = 0

Points 10 to 22

-N = +H = 238

+N = -H = 144

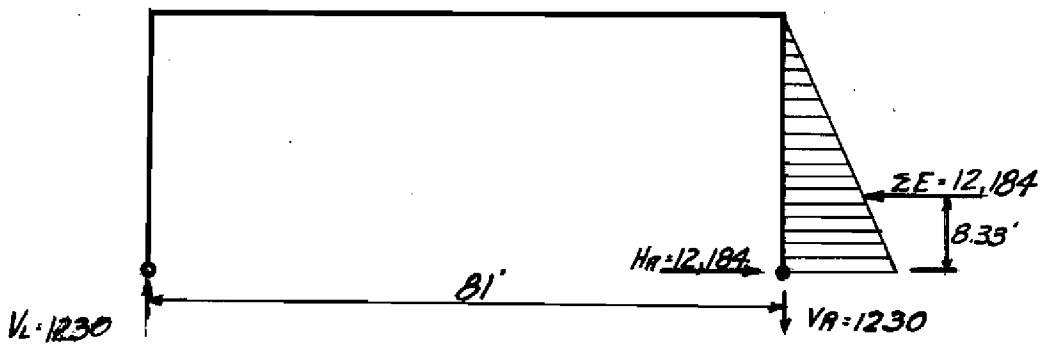
Point 9: +N = 144x.71 = -102, -N= +238x.71 = +169

EARTH PRESSURE RT.

| Point | Vertical Distance from 0 | Vertical Distance Between | Earth Pressure Right – Horizontal Loads: Loads | Sum of Loads | Inc. of Mom. | Partial Mom A | Nor. Dist. From 0 = X | Mom B = Vx | Sub-Total $M_a/M_b$ |
|---|---|---|---|---|---|---|---|---|---|
| H1 | 0 | 05 | 12,184 | 12,184 | 6,092 | +6092 | | | |
| E1 | .5 | .5 | 2,044 | 10,140 | 5,070 | +11162 | | | |
| 1R | 1.0 | 1.5 | | 10,140 | 15,210 | +26372 | | | +26372 |
| E2 | 2.5 | 1.5 | 2,205 | 7,935 | 11,890 | +38262 | | | |
| 2R | 4.0 | 1.5 | | 7,935 | 11,890 | +50152 | | | +50152 |
| E3 | 5.5 | 1.5 | 1,935 | 6,000 | 9,000 | +59152 | | | |
| 3R | 7.0 | 1.5 | | 6,000 | 9,000 | +68152 | | | +68152 |
| E4 | 8.5 | 1.5 | 1,665 | 4,335 | 6,525 | +74,677 | | | |
| 4R | 10.0 | 1.5 | | 4,335 | 6,525 | +81202 | | | +81202 |
| E5 | 11.5 | 1.5 | 1,395 | 2,940 | 4,410 | +85612 | | | |
| 5R | 13.0 | 1.5 | | 2,940 | 4,410 | +90022 | | | +90022 |
| E6 | 14.5 | 1.5 | 1,125 | 1,815 | 2,720 | +92742 | | | |
| 6R | 16.0 | 1.5 | | 1,815 | 2,720 | +95462 | | | +95462 |
| E7 | 17.5 | 1.5 | 855 | 960 | 1,440 | +96902 | | | |
| 7R | 19.0 | 1.5 | | 960 | 1,440 | +98342 | | | +98342 |
| E8 | 20.5 | 1.5 | 585 | 375 | 563 | +98905 | | | |
| 8R | 22.0 | 1.5 | | 375 | 563 | +99468 | | | +99468 |
| 39 | 23.5 | 1.5 | 315 | 60 | 90 | +99558 | | | |
| 9R | 25.0 | .87 | | 60 | 52 | +99610 | | | +99610 |
| 10R | 25.87 | .15 | | 60 | 9 | +99619 | 3 | -3690 | +95929 |
| E10 | 26.02 | .14 | 60 | 0 | 0 | +99619 | | | |
| 11R | 26.16 | .26 | | | | +99619 | 6 | -7380 | +92239 |
| 12R | 26.42 | .23 | | | | +99619 | 9 | -11070 | +88549 |
| 13R | 26.65 | .19 | | | | +99619 | 12 | -14760 | +84849 |
| 14R | 26.84 | .14 | | | | +99619 | 15 | -18450 | +81169 |
| 15R | 26.98 | .12 | | | | +99619 | 18 | -22140 | +77479 |
| 16R | 27.10 | .12 | | | | +99619 | 21 | -25830 | +73789 |
| 17R | 27.22 | .08 | | | | +99619 | 24 | -29520 | +70099 |
| 18R | 27.30 | .08 | | | | +99619 | 27 | -33210 | +66409 |
| 19R | 27.38 | .08 | | | | +99619 | 30 | -36900 | +62719 |
| 20R | 27.46 | .04 | | | | +99619 | 33 | -40590 | +59029 |
| 21R | 27.50 | .0 | | | | +99619 | 36 | -44280 | +55339 |
| 22R | 27.50 | | | | | +99619 | 39 | -27970 | +51649 |
| 22L | 27.50 | | | | | +99619 | 42 | -51660 | +47959 |
| 21L | 27.50 | | | | | +99619 | 45 | -55350 | +44269 |
| 20L | 27.46 | | | | | +99619 | 48 | -59040 | +40579 |
| 19L | 27.38 | | | | | +99619 | 51 | -62730 | +36889 |
| 18L | 27.30 | | | | | +99619 | 54 | -66420 | +33199 |
| 17L | 27.22 | | | | | +99619 | 57 | -70110 | +29509 |
| 16L | 27.10 | | | | | +99619 | 60 | -73800 | +25819 |
| 15L | 26.98 | | | | | +99619 | 63 | -77490 | +22129 |
| 14L | 26.84 | | | | | +99619 | 66 | -81180 | +18439 |
| 13L | 26.65 | | | | | +99619 | 69 | -84870 | +14749 |
| 12L | 26.42 | | | | | +99619 | 72 | -88560 | +11059 |

EARTH PRESSURE RIGHT (Cont'd.)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11L | 26.16 | | | | | +99,619 | 75 | -92,250 | +7,369 |
| 10L | 25.87 | | | | | +99,619 | 78 | -95,940 | +3,679 |
| 9L | 25.0 | | | | | +99,619 | 81 | -99,619 | |
| 8L | 22.0 | | | | | +99,619 | 81 | -99,619 | |
| 7L | 19.0 | | | | | +99,619 | 81 | -99,619 | |
| 6L | 16.0 | | | | | +99,619 | 81 | -99,619 | |
| 5L | 13.0 | | | | | +99,619 | 81 | -99,619 | |
| 4L | 10.0 | | | | | +99,619 | 81 | -99,619 | |
| 3L | 7.0 | | | | | +99,619 | 81 | -99,619 | |
| 2L | 4.0 | | | | | +99,619 | 81 | -99,619 | |
| 1L | 1.0 | | | | | +99,619 | 81 | -99,619 | |




$$V_l \quad V_r = \frac{12,184 \times 8.33}{81} = 1230 \#$$

Points 2 to 8

$N = V = 1429$

Points 10 to 22

$N = H = 1852$

Point 9L

$N = (.71 \times 1852) + (.71 \times 1429) = +2330$

Point 9R

$N = (.71 \times 1852) - (.71 \times 1429) = + 300$

EARTH PRESSURE RIGHT - Cont'd.

| Point | Y | I | $\frac{My}{I}$ | Hy | Total Mom. |
|---|---|---|---|---|---|
| 1R | 1 | 62.06 | | - 1,852 | - |
| 2R | 4 | 4.51 | 43,500 | - 7,408 | +42,744 |
| 3R | 7 | 5.80 | 82,300 | -12,964 | +55,188 |
| 4R | 10 | 7.32 | 111,000 | -18,520 | +62,682 |
| 5R | 13 | 9.76 | 120,000 | -24,076 | +65,946 |
| 6R | 16 | 11.86 | 128,800 | -29,632 | +65,830 |
| 7R | 19 | 14.29 | 130,700 | -35,188 | +63,154 |
| 8R | 22 | 17.10 | 128,000 | -40,744 | +58,724 |
| 9R | 25 | 19.96 | 124,800 | -46,300 | +53,310 |
| 10R | 25.87 | 14.14 | 175,300 | -48,000 | +47,929 |
| 11R | 26.16 | 9.79 | 246,200 | -48,400 | +43,839 |
| 12R | 26.42 | 6.87 | 340,500 | -49,000 | +39,549 |
| 13R | 26.65 | 4.90 | 461,500 | -49,400 | + 35,449 |
| 14R | 26.84 | 3.69 | 591,000 | -49,700 | +31,469 |
| 15R | 26.98 | 2.85 | 733,000 | -50,000 | +27,479 |
| 16R | 27.10 | 2.23 | 897,000 | -50,200 | +23,589 |
| 17R | 27.22 | 1.70 | 1,122,000 | -50,500 | +19,599 |
| 18R | 27.30 | 1.53 | 1,183,000 | -50,600 | +15,809 |
| 19R | 27.38 | 1.25 | 1,373,000 | -50,700 | +12,019 |
| 20R | 27.46 | 1.00 | 1,620,000 | -50,900 | + 8,129 |
| 21R | 27.50 | 0.89 | 1,710,000 | -51,000 | +4, 339 |
| 22R | 27.50 | 0.89 | 1,597,000 | -51,000 | + 649 |
| 22L | 27.50 | 0.89 | 1,480,000 | -51,000 | - 3,041 |
| 21L | 27.50 | 0.89 | 1,368,000 | -51,000 | - 6,731 |
| 20L | 27.46 | 1.00 | 1,113,000 | -50,900 | -10,321 |
| 19L | 27.38 | 1.25 | 808,000 | -50,700 | -13,811 |
| 18L | 27.30 | 1.53 | 593,000 | -50,600 | -17,401 |
| 17L | 27.22 | 1.70 | 472,500 | -50,500 | -20,991 |
| 16L | 27.10 | 2.23 | 314,000 | -50,200 | -24,381 |
| 15L | 26.98 | 2.85 | 209,500 | -50,000 | -27,871 |
| 14L | 26.84 | 3.69 | 134,200 | -49,700 | -31,261 |
| 13L | 26.65 | 4.90 | 80,250 | -49,400 | -34,651 |
| 12L | 26.42 | 6.87 | 42,500 | -49,000 | -37,941 |
| 11L | 26.16 | 9.79 | 19,680 | -48,400 | -41,031 |
| 10L | 25.87 | 14.14 | 6,740 | -48,000 | -44,321 |
| 9L | 25 | 19.96 | - | -46,300 | -46,300 |
| 8L | 22 | 17.10 | - | -40,744 | -40,744 |
| 7L | 19 | 14.29 | - | -35,188 | -35,188 |
| 6L | 16 | 11.86 | - | -29,632 | -29,632 |
| 5L | 13 | 9.76 | - | -24,076 | -24,076 |
| 4L | 10 | 7.32 | - | -18,520 | -18,520 |
| 3L | 7 | 5.80 | - | -12,964 | -12,964 |
| 2L | 4 | 4.51 | - | - 7,408 | - 7,408 |
| 1L | 1 | 62.06 | - | - 1,852 | - |

$$\Sigma = 19,559,970$$

$$H = \frac{19,559,970}{10547.52} = 1852$$

LIVE LOAD MOMENTS

Roadway width = 24'0"

Typical H-20 equivalent loading.

Impact = $\frac{50}{L + 125}$ = $\frac{50}{206}$ = 24%

Load per sq. ft. = $\frac{640}{9}$ x 1.24 = 88.3#

Excess concentration = $\frac{18000}{9}$ x 1.24 = 2,480#

In applying this loading the areas under the influence lines for the loaded length of the structure were determined and multiplied by the amount of the uniform load. To this was added the moment due to the effect of the excess concentration. In all cases, the load was placed so as to give the maximum conditions of loading.

Thrust factors NF, are V for points 2 to 8, and H for points 10 to 22. For point 9 it is the sum of the components of H and V at 45°.

The areas under the curves as well as the individual values of the curves at certain points are tabulated under the headings MF and NF. The areas under the curves are the summations of the values at the panel points so the product of MF and load per square foot must be multiplied by 3 to give correct results, since each center of division has the load from 3 lineal feet of bridge.

| Load | Point 2 MF | M | NF | N | Point 3 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -3342 | -8853 | 13.50 | 3576 | -59.26 | -15,698 | 13.50 | 3576 |
| C.L.L. | - 207 | -5134 | .50 | 1240 | - 3.60 | - 8,928 | .50 | 1240 |
| Total | | -13987 | | 4816 | | -24,626 | | 4816 |

| Load | Point 4 MF | M | NF | N | Point 5 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -84.48 | -22,379 | 13.50 | 3576 | -109.94 | -29,123 | 13.50 | 35.76 |
| C.L.L. | - 5.15 | -12,772 | .50 | 1240 | - 6.70 | -16,616 | .50 | 12.40 |
| Total | | -35,151 | | 4816 | | -45,739 | | 48.16 |

| Load | Point 6 MF | M | NF | N | Point 7 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -135.10 | -35,788 | 1350 | 3576 | -160.72 | -42,575 | 13.50 | 3576 |
| C.L.L. | - 8.23 | -20,410 | .50 | 1240 | -9.78 | -24,254 | .50 | 1240 |
| Total | | -56,198 | | 4816 | | -66,829 | | 4816 |

| Load | Point 8 MF | M | NF | N | Point 9 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -186.16 | -49,314 | 13.50 | 3576 | -211.34 | -55,984 | 15.37 | 2240 |
| C.L.L. | - 11.35 | -28,148 | .50 | 1240 | - 12.85 | -31,868 | .71 | 1754 |
| Total | | -77,462 | | 4816 | | -87,852 | | 3994 |

| Load | Point 10 MF | M | NF | N | Point 10 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -182.11 | -48,241 | 8.41 | 2227 | + 1.50 | +397 | .05 | 13 |
| C.L.L. | - 11.85 | -29,388 | .51 | 1265 | + 1.50 | +3720 | .05 | 124 |
| Total | | -77,629 | | 3492 | | +4117 | | 137 |

| Load | Point 11 | | | | Point 11 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -151.77 | -40,204 | 8.14 | 2158 | +5.18 | +1372 | .32 | 85 |
| C.L.L. | -10.55 | -26,164 | .51 | 1265 | +2.65 | +6572 | .11 | 273 |
| | | -66,368 | | 3423 | | +7944 | | 358 |

| Load | Point 12 | | | | Point 12 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -125.70 | -33298 | 7.68 | 2035 | +10.35 | +2742 | .78 | 206 |
| C.L.L. | - 9.33 | -23138 | .51 | 1265 | + 3.92 | +9722 | .16 | 397 |
| | | -56436 | | 3300 | | +12464 | | 603 |

| Load | Point 13 | | | | Point 13 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -102.84 | -27,242 | 7.37 | 1953 | +15.47 | +4098 | 1.09 | 289 |
| C.L.L. | - 8.08 | -20,038 | .51 | 1265 | + 4.65 | +11532 | .21 | 521 |
| | | -47,280 | | 3318 | | +15,630 | | 810 |

| Load | Point 14 | | | | Point 14 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -82.77 | -21,926 | 7.02 | 1860 | +20.59 | +5454 | 1.44 | 382 |
| C.L.L. | - 6.93 | -17,186 | .49 | 1215 | + 5.27 | +13070 | .26 | 645 |
| | | -39,112 | | 3075 | | +18524 | | 1027 |

| | Point 15 | | | | Point 15 | | | |
|---|---|---|---|---|---|---|---|---|
| Load | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -65.18 | -17266 | 6.20 | 1640 | + 25.76 | +6824 | 2.26 | 600 |
| C.L.L. | - 5.80 | -14384 | .49 | 1215 | + 5.70 | +14136 | .31 | 769 |
| | | -31650 | | 2855 | | +20960 | | 1369 |

| Load | Point 16 | | | | Point 16 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -49.57 | -13131 | 5.74 | 1520 | +30.52 | +8085 | 2.72 | 721 |
| C.L.L. | -4.72 | -11706 | .46 | 1140 | + 6.05 | +15004 | .35 | 869 |
| | | -24837 | | 2660 | | +23089 | | 1590 |

| Load | Point 17 | | | | Point 17 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -36.29 | -9615 | 5.25 | 1390 | +33.57 | +8893 | 3.21 | 850 |
| C.L.L. | - 3.68 | -9126 | .46 | 1140 | + 6.19 | +15351 | .39 | 968 |
| | | -18739 | | 2530 | | +24244 | | 1818 |

| Load | Point 18 | | | | Point 18 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -24.49 | -6487 | 4.75 | 1260 | +36.43 | +9650 | 3.71 | 985 |
| C.L.L. | - 2.72 | -6746 | .43 | 1067 | + 6.28 | +15574 | .43 | 1067 |
| | | -13233 | | 2327 | | +25224 | | 2052 |

| Load | Point 19 | | | | Point 19 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | -15.49 | -4103 | 3.72 | 986 | +38.25 | +10,132 | 4.74 | 1260 |
| C.L.L. | - 1.93 | -4786 | .39 | 968 | + 6.27 | +15,550 | .46 | 1140 |
| | | -8889 | | 1954 | | +25,682 | | 2400 |

| Load | Point 20 | | | | Point 20 | | | |
|---|---|---|---|---|---|---|---|---|
| | MF | M | NF | N | MF | M | NF | N |
| U.L.L. | - 7.81 | -2069 | 3.22 | 854 | +39.65 | +10503 | 5.24 | 1390 |
| C.L.L. | - 1.15 | -2852 | .35 | 869 | + 6.23 | +15450 | .49 | 1215 |
| | | -4921 | | 1723 | | +25,953 | | 2605 |

| Load | Point 21 MF | M | NF | N | Point 21 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -2.43 | -644 | 1.84 | 488 | +40.02 | +10601 | 6.62 | 1755 |
| C.L.L. | - .43 | -1066 | .26 | 645 | + 6.17 | +15302 | .51 | 1265 |
| | | -1710 | | 1133 | | +25903 | | 3020 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| Load | Point 22 MF | M | NF | N | Point 22 MF | M | NF | N |
|---|---|---|---|---|---|---|---|---|
| U.L.L. | -.22 | -58 | .54 | 143 | +4054 | +10739 | 7.92 | 2100 |
| C.L.L. | -.10 | -248 | .11 | 273 | +6.13 | +15202 | .51 | 1265 |
| | | -306 | | 416 | | +25,941 | | 3365 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

SUMMARY OF MOMENTS AND THRUSTS

| Loading | Point 2 M | Point 2 N | Point 3 M | Point 3 N |
|---|---|---|---|---|
| Dead | -43,776 | 38,848 | - 79,512 | 37,198 |
| Earth Press. Rt. | +42,744 | -1,429 | + 55,188 | -1,429 |
| Earth Press. Lt. | - 7,408 | -1,429 | - 12,964 | 1,429 |
| Sub-total | -8,440 | +38,848 | - 37,288 | +37,198 |
| | | | | |
| Live + | | | | |
| Live - | -13,987 | 4,816 | -24,626 | 4,816 |
| Temperature + | + 576 | | + 1,008 | |
| Temperature - | - 953 | | - 1,665 | |
| | | | | |
| Max. Total ± | -23,380 | 43,664 | -63,579 | 42,014 |

| Loading | Point 4 M | Point 4 N | Point 5 M | Point 5 N |
|---|---|---|---|---|
| Dead | -113,282 | 35,398 | -147,420 | 33,448 |
| Earth Press. Rt. | + 62,682 | - 1,429 | + 65,946 | - 1,429 |
| Earth Press. Lt. | - 18,520 | 1,429 | - 24,076 | 1,429 |
| Sub-total | -69,120 | +35,398 | -105,550 | 33,448 |
| | | | | |
| Live + | | | | |
| Live - | -35,151 | 4,816 | -45,739 | 4,816 |
| Temperature + | + 1,440 | | + 1,873 | |
| Temperature - | - 2,380 | | - 3,095 | |
| | | | | |
| Max. Total ± | - 106,651 | 40,214 | -154,384 | 38,264 |

| Loading | Point 6 M | Point 6 N | Point 7 M | Point 7 N |
|---|---|---|---|---|
| Dead | -180,960 | 31,338 | -215,540 | 29,078 |
| Earth Press. Rt. | + 65,830 | - 1,429 | + 63,154 | -1,429 |
| Earth Press. Lt. | - 29,637 | 1,429 | - 35,188 | 1,429 |
| Sub-total | -144,762 | 31,338 | -187,574 | 29,078 |
| | | | | |
| Live + | | | | |
| Live - | - 56,198 | 4,816 | - 66,829 | 4,816 |
| Temperature + | + 2,305 | | + 2,735 | |
| Temperature - | - 3,810 | | - 4,525 | |
| | | | | |
| Max. Totals ± | - 204,770 | 36,154 | -258,928 | 33,894 |

SUMMARY OF MOMENTS AND THRUSTS - Cont'd.

| Loading | Point 8 M | Point 8 N | Point 9 M | Point 9 N |
|---|---|---|---|---|
| Dead | -249,870 | 27,673 | -283,710 | 25,850 |
| Earth Press.Rt. | + 58,724 | - 1,429 | + 53,310 | 300 |
| Earth Press.Lt. | - 40,744 | 1,429 | - 46,300 | 2,330 |
| Sub-total | -231,890 | 27,673 | -276,700 | 28,480 |
| Live + | | | | |
| Live - | - 77,462 | 4,816 | - 87,852 | 3,994 |
| Temperature + | + 3,170 | | + 3,600 | - 102 |
| Temperature - | - 5,240 | | - 5,960 | + 169 |
| Max.Total ± | -314,592 | 32,489 | -370,512 | 32,643 |

| Loading | Point 10 M | Point 10 N | Point 11 M | Point 11 N |
|---|---|---|---|---|
| Dead | -231,592 | 11,334 | -183,316 | 11,334 |
| Earth Press. Rt. | +47,929 | 1,852 | + 43,839 | 1,852 |
| Earth Press. Lt. | -44,321 | 1,852 | - 41,031 | 1,852 |
| Sub-total | -227,984 | 15,038 | -180,508 | 15,038 |
| Live + | + 4,117 | 137 | + 7,944 | 358 |
| Live - | - 77,629 | 3,492 | - 66,368 | 3,423 |
| Temperature + | + 3,730 | 144 | + 3,762 | 144 |
| Temperature - | - 6,160 | 238 | - 6,230 | 238 |
| Max. Total ± | -311,773 | 18,768 | -253,106 | 18,699 |

| Loading | Point 12 M | Point 12 N | Point 13 M | Point 13 N |
|---|---|---|---|---|
| Dead | -139,358 | 11,334 | -102,369 | 11,334 |
| Earth Press. Rt. | + 39,549 | 1,852 | + 35,449 | 1,852 |
| Earth Press. Lt. | - 37,941 | 1,852 | - 34,651 | 1,852 |
| Sub-total | -137,750 | 15,038 | -101,571 | 15,038 |
| Live + | + 12,464 | 603 | + 15,630 | 810 |
| Live - | - 56,436 | 3,300 | - 47,280 | 3,218 |
| Temperature + | + 3,810 | 144 | + 3,840 | 144 |
| Temperature - | - 6,290 | 238 | - 6,350 | 238 |
| Max.Total ± | -200,476 | 18,576 | - 155,201 | 18,494 |

SUMMARY OF MOMENTS AND THRUSTS -Cont'd.

| Loading | Point 14 | | Point 15 | |
|---|---|---|---|---|
| | M | N | M | N |
| Dead | -69,925 | 11,334 | -42,034 | 11,334 |
| Earth Press.Rt. | +31,469 | 1,852 | +27,479 | 1,852 |
| Earth " Lt. | -31,261 | 1,852 | -27,871 | 1,852 |
| Sub-total | -69,717 | 15,038 | -42,426 | 15,038 |
| | | | | |
| Live + | +18,524 | 1,027 | +20,960 | 1,369 |
| Live - | -39,112 | 3,075 | -31,650 | 2,855 |
| Temperature + | + 3,867 | 144 | + 3,885 | 144 |
| Temperature - | - 6,400 | 238 | - 6,425 | 238 |
| Max. Total ± | ±115,229 | 18,351 | -80,501 | 18,131 |

| Loading | Point 16 | | Point 17 | |
|---|---|---|---|---|
| | M | N | M | N |
| Dead | -19,770 | 11,334 | +1511 | 11,334 |
| Earth Press.Rt. | +23,589 | 1,852 | +19599 | 1,852 |
| Earth Press. Lt. | -24,381 | 1,852 | -20991 | 1,852 |
| Sub-Total | -20,562 | 15038 | +119 | 15038 |
| | | | | |
| Live + | +23089 | 1,590 | +24,244 | 1818 |
| Live - | -24837 | 2,660 | -18,739 | 2530 |
| Temperature + | + 3905 | 144 | + 3,920 | 144 |
| Temperature - | - 6450 | 238 | - 6,490 | 238 |
| + | + 6,432 | 16,772 | +28,283 | 17,000 |
| Max. Total - | -51,849 | 17,938 | -25,110 | 17,806 |

| Loading | Point 18 | | Point 19 | |
|---|---|---|---|---|
| | M | N | M | N |
| Dead | +16,899 | 11,334 | +28,271 | 11,334 |
| Earth Press. Rt. | +15,809 | 1,852 | +12,019 | 1,852 |
| Earth Press. Lt. | -17,401 | 1,852 | -13,811 | 1,852 |
| Sub-Total | +15,307 | 15,038 | +26,479 | 15,038 |
| | | | | |
| Live + | +25,224 | 2,052 | +25,682 | 2,400 |
| Live - | -13,233 | 2,327 | - 8,889 | 1,954 |
| Temperature + | + 3,935 | 144 | +3,942 | 144 |
| Temperature - | - 6,510 | 238 | -6,520 | 238 |
| + | +44,466 | 17,234 | +56,103 | 17,582 |
| Max. Total | - 4,436 | 17,603 | | |

SUMMARY OF MOMENTS AND THRUSTS - Cont'd.

| Loading | Point 20 M | Point 20 N | Point 21 M | Point 21 N |
|---|---|---|---|---|
| Dead | + 36,032 | 11,334 | + 44077 | 11,334 |
| Earth Press. Rt. | + 8,129 | 1,852 | + 4339 | 1,852 |
| Earth Press. Lt. | - 10,321 | 1,852 | - 6731 | 1,852 |
| Sub-total | + 33,840 | 15,038 | + 41685 | 15,038 |
| | | | | |
| Live + | + 25,953 | 2,605 | + 25903 | 3,020 |
| Live - | - 4,921 | 1,723 | - 1710 | 1,133 |
| Temperature + | + 3,958 | 144 | + 3962 | 144 |
| Temperature - | - 6,540 | 238 | - 6550 | 238 |
| + | + 63,751 | 17,787 | + 71550 | 18,202 |
| Max. Total - | | | | |

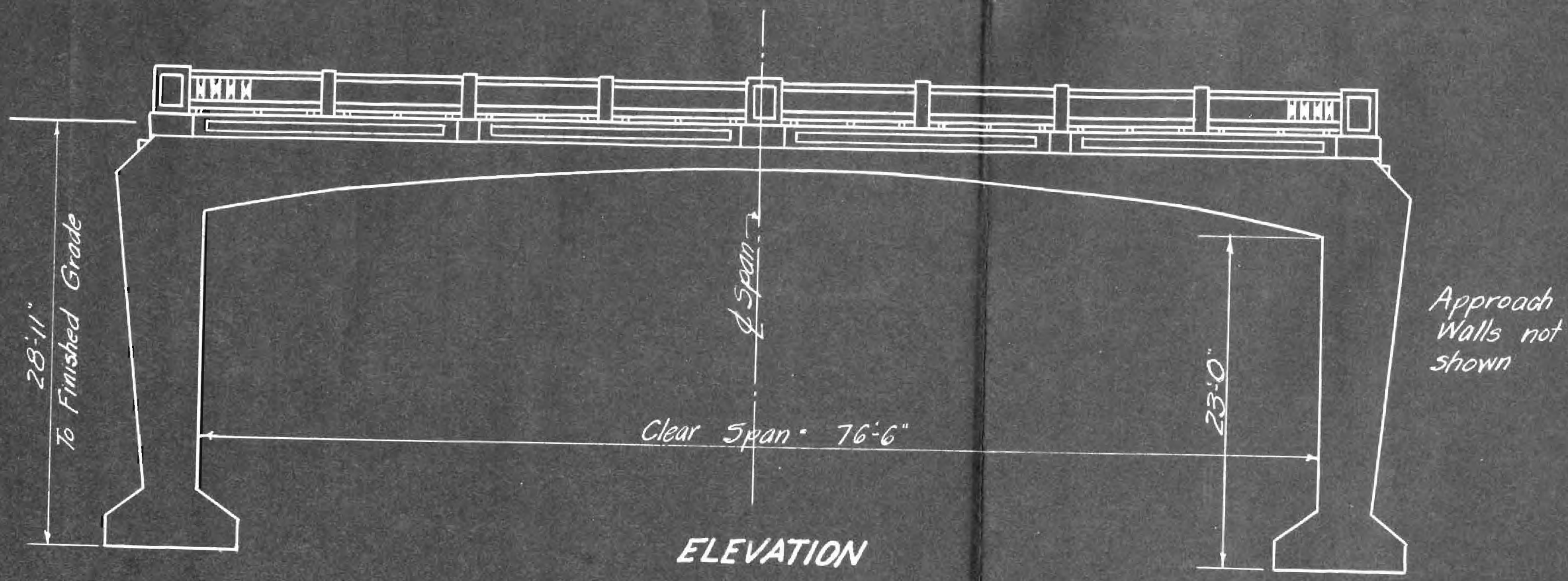
| Loading | Point 22 M | Point 22 N |
|---|---|---|
| Dead | + 46,826 | 11,334 |
| Earth Press.Rt. | + 649 | 1,852 |
| Earth Press. Lt. | - 3,041 | 1,852 |
| Sub-total | + 44,434 | 15,038 |
| | | |
| Live + | + 25,941 | 3,365 |
| Live - | - 306 | 416 |
| Temperature + | + 3,962 | 144 |
| Temperature - | - 6,550 | 238 |
| + | + 74,337 | 18,547 |
| Max. Total - | | |
| | | |

DESIGN OF SECTIONS

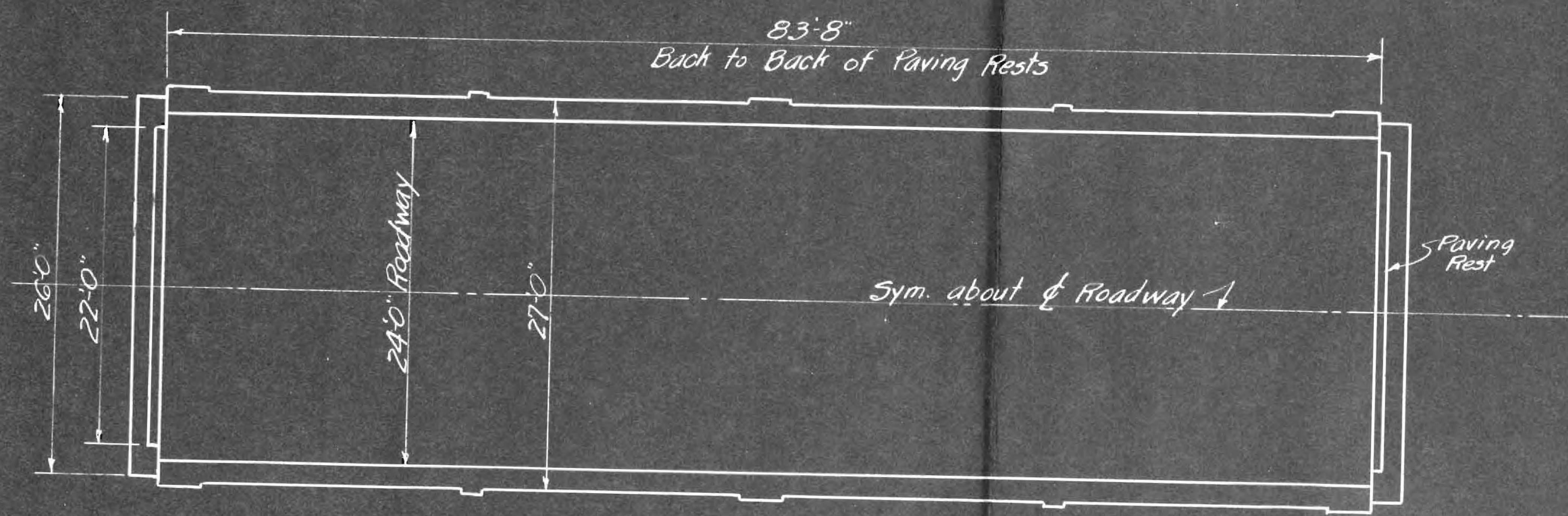
| Point | Moment Ft.Lbs. | Moment Inch Lbs. | N Pounds | $e = M \div N$ Inches | t Inches | $d = t - 2''$ | $e' = e + \frac{t}{2} - 2''$ |
|---|---|---|---|---|---|---|---|
| 2 | -23,380 | -280,300 | 45664 | 6.43 | 44 | 42 | 26.43 |
| 3 | -63,576 | -763,800 | 42014 | 16.17 | 48 | 46 | 40.17 |
| 4 | -106,651 | -1,278,000 | 40214 | 31.77 | 52 | 50 | 55.77 |
| 5 | -154,384 | -1,852,000 | 38264 | 48.40 | 56.25 | 54.25 | 74.55 |
| 6 | -204,770 | -2,459,000 | 36154 | 68.05 | 60.25 | 58.25 | 96.18 |
| 7 | -258,928 | -3,110,000 | 33894 | 91.80 | 64.25 | 62.25 | 121.95 |
| 8 | -314,592 | -3,757,000 | 32489 | 115.40 | 68.25 | 66.25 | 147.52 |
| 9 | -370,512 | -4,449,000 | 32643 | 136.20 | 72.00 | 70.00 | 170.20 |
| 10 | -311,773 | -3,740,000 | 18768 | 199.40 | 64.00 | 62.00 | 229.40 |
| 11 | -253,106 | -3,038,000 | 18699 | 162.50 | 57.00 | 55.00 | 189.00 |
| 12 | -200,476 | -2,458,000 | 18576 | 132.30 | 50.50 | 48.50 | 155.55 |
| 13 | -155,201 | -1,863,000 | 18494 | 100.70 | 45.00 | 43.00 | 121.20 |
| 14 | -115,229 | -1,382,500 | 18351 | 74.40 | 40.50 | 38.50 | 92.65 |
| 15 | - 80,501 | - 966,000 | 18131 | 53.25 | 37.00 | 35.00 | 79.75 |
| 16 | - 51,849 | - 622,500 | 17938 | 34.70 | 34.00 | 32.00 | 49.70 |
| 16 | + 6,432 | + 77,180 | 16772 | 4.60 | 34.00 | 32.00 | 19.60 |
| 17 | - 25,110 | - 301,500 | 17806 | 16.93 | 31.00 | 29.00 | 30.43 |
| 17 | + 28,283 | + 339,600 | 17000 | 19.97 | 31.00 | 29.00 | 33.47 |
| 18 | - 4,436 | - 53,270 | 17603 | 3.02 | 29.00 | 27.00 | 15.52 |
| 18 | + 44,466 | + 533,500 | 17234 | 30.90 | 29.00 | 27.00 | 63.40 |
| 19 | + 56,103 | + 674,500 | 17582 | 38.35 | 27.00 | 25.00 | 49.85 |
| 20 | + 63,751 | + 765,500 | 17787 | 43.05 | 25.00 | 23.00 | 53.55 |
| 21 | + 71,550 | + 859,000 | 18202 | 47.15 | 24.00 | 22.00 | 57.15 |
| 22 | + 74,337 | + 892,500 | 18547 | 48.10 | 24.00 | 22.00 | 58.14 |

## DESIGN OF SECTIONS

| Point | $\frac{e'}{d}$ | $K = \frac{Ne'}{bd^2}$ | $f_c$ Pounds Per Sq.In. | $f_s$ Pounds Per S. In. | Required P | Required As Sq.Ins. Per Ft. Width | Point |
|---|---|---|---|---|---|---|---|
| 2 | .63 | 54.6 | 490 | 18000 | | | 2 |
| 3 | .87 | 66.2 | 550 | 18000 | | | 3 |
| 4 | 1.11 | 74.5 | 590 | 18000 | .0009 | .54 | 4 |
| 5 | 1.37 | 80.5 | 620 | 18000 | .0017 | 1.11 | 5 |
| 6 | 1.65 | 85.4 | 640 | 18000 | .0024 | 1.68 | 6 |
| 7 | 1.96 | 88.9 | 660 | 18000 | .0030 | 2.24 | 7 |
| 8 | 2.23 | 91.1 | 660 | 18000 | .0032 | 2.52 | 8 |
| 9 | 2.43 | 94.5 | 680 | 18000 | .0037 | 3.11 | 9 |
| 10 | 3.76 | 94.9 | 680 | 18000 | .0044 | 3.28 | 10 |
| 11 | 3.44 | 97.5 | 700 | 18000 | .0048 | 3.17 | 11 |
| 12 | 3.21 | 102.3 | 710 | 18000 | .0044 | 2.56 | 12 |
| 13 | 2.82 | 101.0 | 710 | 18000 | .0042 | 2.17 | 13 |
| 14 | 2.40 | 95.4 | 680 | 18000 | .0037 | 1.71 | 14 |
| 15 | 2.28 | 98.5 | 700 | 18000 | .0039 | 1.64 | 15 |
| -16 | 1.55 | 72.4 | 575 | 18000 | .0018 | .69 | 16 |
| +16 | .61 | 26.6 | 330 | 18000 | - | - | 16 |
| -17 | 1.05 | 53.7 | 725 | 18000 | .0010 | .35 | 17 |
| +17 | 1.15 | 56.2 | 500 | 18000 | .0007 | .25 | 17 |
| -18 | .58 | 31.5 | 350 | 18000 | - | - | 18 |
| +18 | 2.34 | 124.5 | 800 | 17500 | .0050 | 1.62 | 18 |
| 19 | 1.99 | 116.5 | 780 | 18000 | .0040 | 1.20 | 19 |
| 20 | 2.35 | 150.0 | 800 | 12000 | .0090 | 2.48 | 20 |
| 21 | 2.60 | 179.3 | 800 | 8000 | .0181 | 4.78 | 21 |
| 22 | 2.64 | 185.8 | 800 | 7000 | .0210 | 5.30 | 22 |




ELEVATION




PLAN

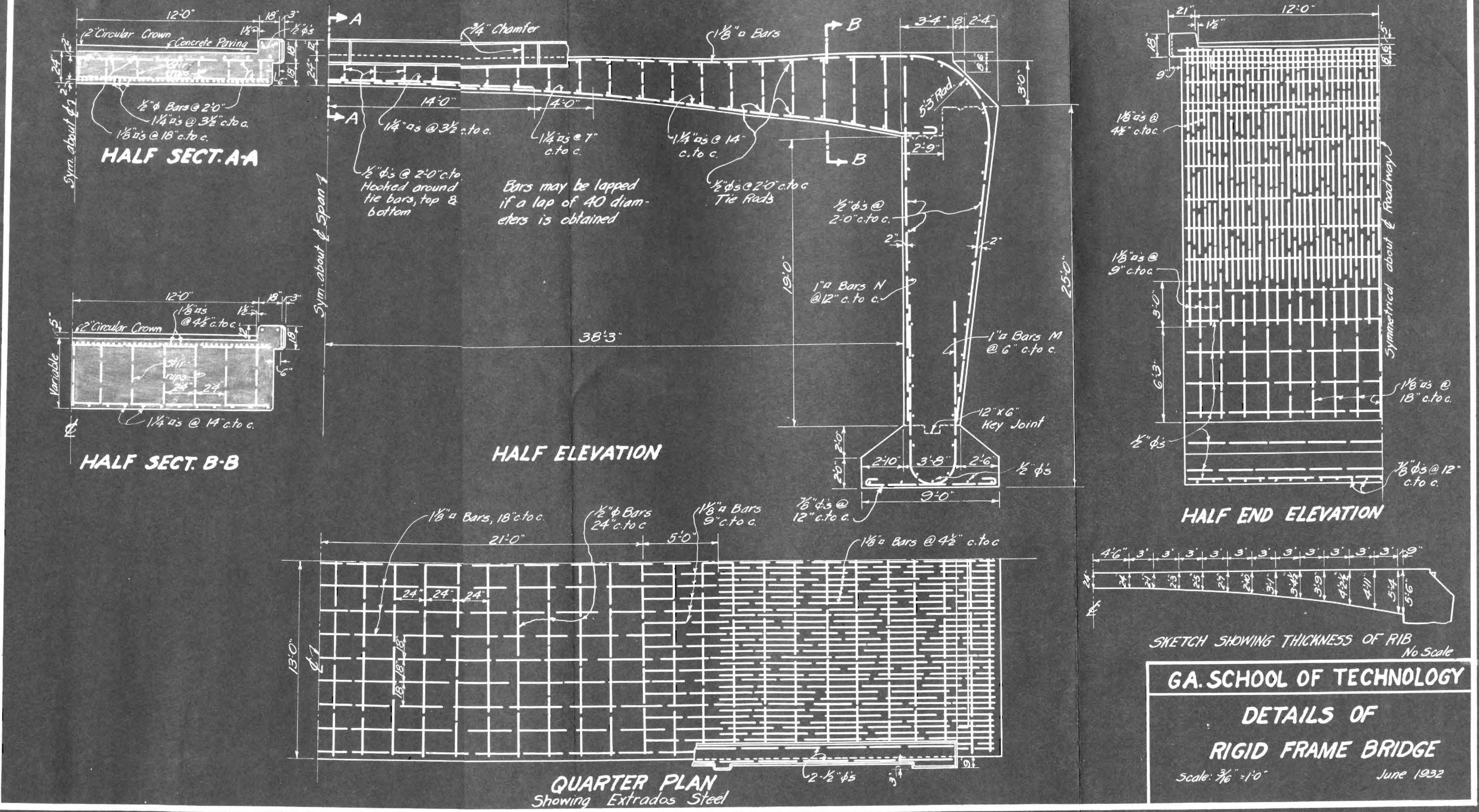
## GENERAL NOTES

Loading: Typical H-20. Impact Allowed.
Concrete: 1-2-3½ mix. Maximum size of aggregate, 1½"
Reinforcing of steel bars
Chamfer all exposed edges ¾", unless noted.
Back face of vertical legs spade finish.
Other parts rubbed finish.

GA. SCHOOL OF TECHNOLOGY

PLAN AND ELEVATION
RIGID FRAME BRIDGE

Scale: 1" = 8'-0"    June 1932




GA. SCHOOL OF TECHNOLOGY

DETAILS OF RIGID FRAME BRIDGE

Scale: 3/16" = 1'-0"

June 1932

# EXPERIMENTATION

## EXPERIMENTATION

As mentioned before, the rigid frame bridge is no longer a mere experiment. Before the practicability of its design could be assured many tests were carried out. The Westchester County Park Commission instigated a great number of these tests and the results have influenced the development of the design greatly.

Probably the first question to be raised by those who were skeptical as to the safety of the type was the problem of the stress conditions around the knee, that is, around the bend at the juncture of the vertical leg and the rib proper. In answer to the question, a number of laboratory tests were made on right angled knees of reinforced concrete. It was found that the detail had sufficient safety but also that a peculiar situation existed. The greater the load that was applied the closer the neutral axis in the concrete approached the inside of the knee. As can be seen, this would call for an extremely high compression in the concrete - in fact, one that would be prohibitive. This peculiar location of the axis was verified by photo-elastic analysis also. There remained then the task of corrolating these two facts; that the detail was safe, and that very high compressive stresses were produced. The explanation of this, however, is that the compressive stress which concrete can be depended upon to carry is a great deal higher if the pressure comes from all sides at once. In other words, the concrete at the knee of the rigid frame is subjected to a confined stress. In ordinary compression tests on concrete specimens, the failure is always due to shearing off of the specimen on an inclined plane. If this specimen were compressed on all faces with equal forces a very high compressive stress would be indicated. Some bridges have been constructed using filleted knee joints in an attempt to move the neutral axis farther from the compressive face, but since the unfilleted knees have proven their safety and their appearance is more pleasing, the fillets are not used very often.

The deformeter method of analyzing the behavior of highly indeterminate structures has yielded very gratifying results. The procedure is to construct a flat model of the structure from some elastic material, making the depth of any section in proportion to the cube root of the gross moment of inertia of the corresponding section of the original structure. Then deflections of known magnitude are caused at one section of the structure and the relative deflection at other sections studied. When the proper apparatus is available this method is extremely satisfactory and results can be obtained in close agreement with the laborious mathematical results, at a great saving in time and trouble. Filar micrometer microscopes are necessary as well as specially constructed plugs and plug bars for causing deflections. It should be noticed that, in all cases, the gross moment of inertia is used. The reason for this is that the theory of the design depends on the flexure in the structure and the flexure is caused by the action of the whole cross-section and not by occasional sections where the moment of inertia is less. Applied to a reinforced concrete bridge this means that the flexure is caused, not by an occasional cracked section, but by the flexure due to tension and compression of the whole cross-section.

Two concrete models were constructed by the Bronx Parkway

Commission and loaded to destruction. The safety of the design was proven by the fact that stresses of 79000 and 4900 lbs. per sq. in. in steel and concrete, respectively, were calculated at the point of failure. The failure occurred at the center of the crown since the applied load was concentrated at that point. An additional factor of safety was noticed in these field models that is both interesting and valuable. Upon failure of the concrete in compression at the crown, the structure did not fall but continued to support the load acting then as two half arches, hinged at the crown by the action of the steel at that point. This additional factor of safety, it can easily be seen, is most desirable and is a characteristic not possessed by the simple beam type of bridges.

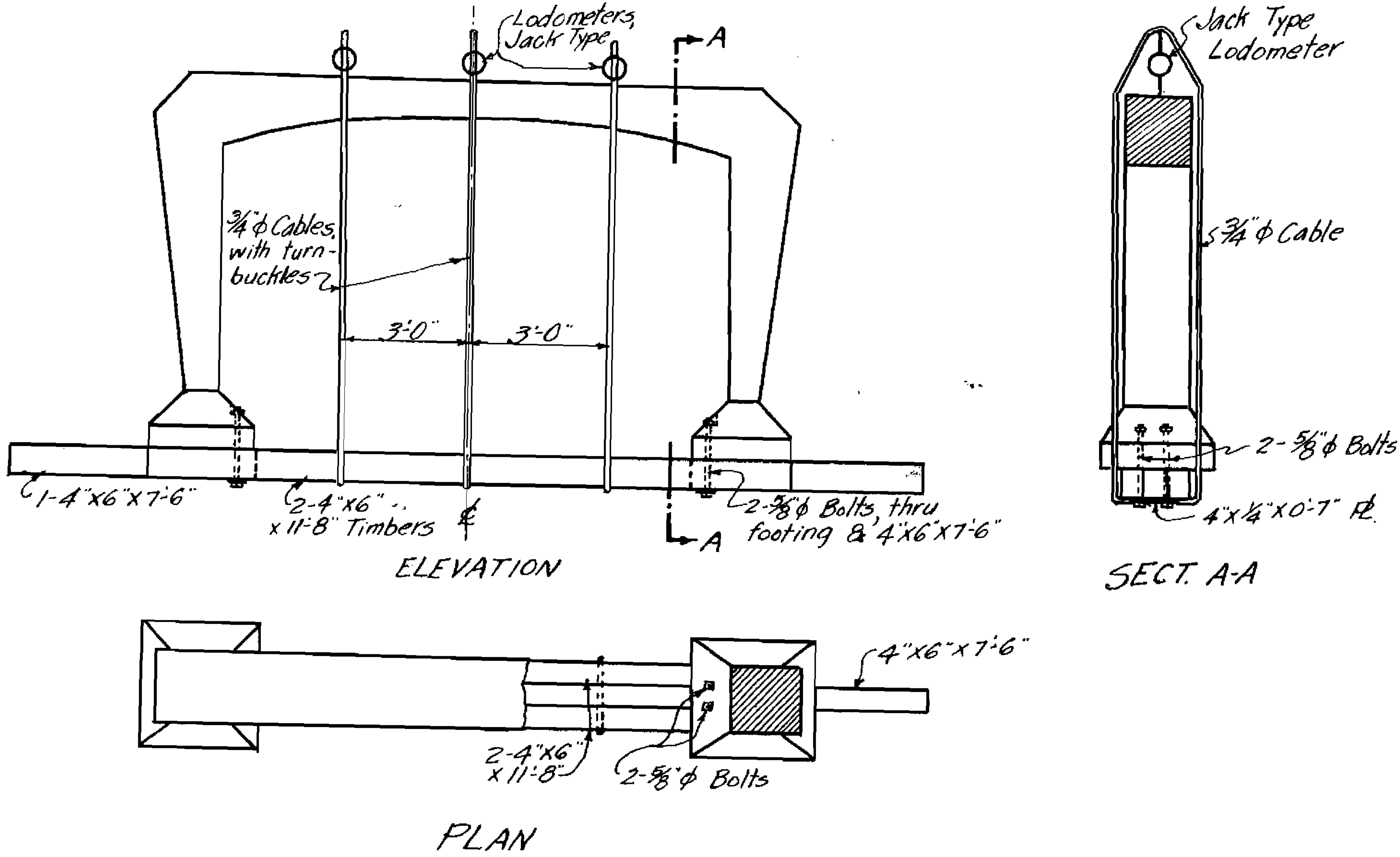
The model constructed by the writer was designed as a free end rigid frame. It has a clear span of 9'-4" and a height of approximately 6'-0" from bottom of footings to top of rib. It was designed to carry live loads of 1000 lbs. at center of span and 1000 lbs. at points 3 ft. on each side of the center. These loads were arbitrarily assumed since it was thought that these conditions could be realized with the facilities available for loading the bridge. Several pictures made of the bridge during and after construction are included. The model was made with a width of 1 ft. since the tests could be made on a 1 ft. wide model as well as on a wider one.

A hole approximately 5 ft. wide, 12 ft. long and 5 ft. deep was dug in which to construct the bridge. This was done for two reasons; first, to permit easy placing of the approach fills on the ends of the bridge; and second, to facilitate pouring the concrete without the use of a ramp or other such device. The earth at the ends of the structure was dug back approximately 5 ft. at both ends so that the earth could be backfilled and actual structural conditions similated.

The next problem was that of devising a method of loading the bridge. To do this it was decided to construct the bridge with two 4"x6" timbers running under the footings from one footing to the other. Under these timbers, at the midpoints, and at 3' each side of the midpoint, 3/4" Ø cables of sufficient length to form a loop over the top of the rib were placed. The two ends of the cable could be clamped together forming a continuous loop under the timbers and over the bridge. A jack-type lodometer was to be used between the cable and the top of the rib. Then when the jack was used against the cable it was equivalent to a load being applied to the bridge, and the amount of the load could be determined. Fig. 10 shows a sketch of this arrangement.

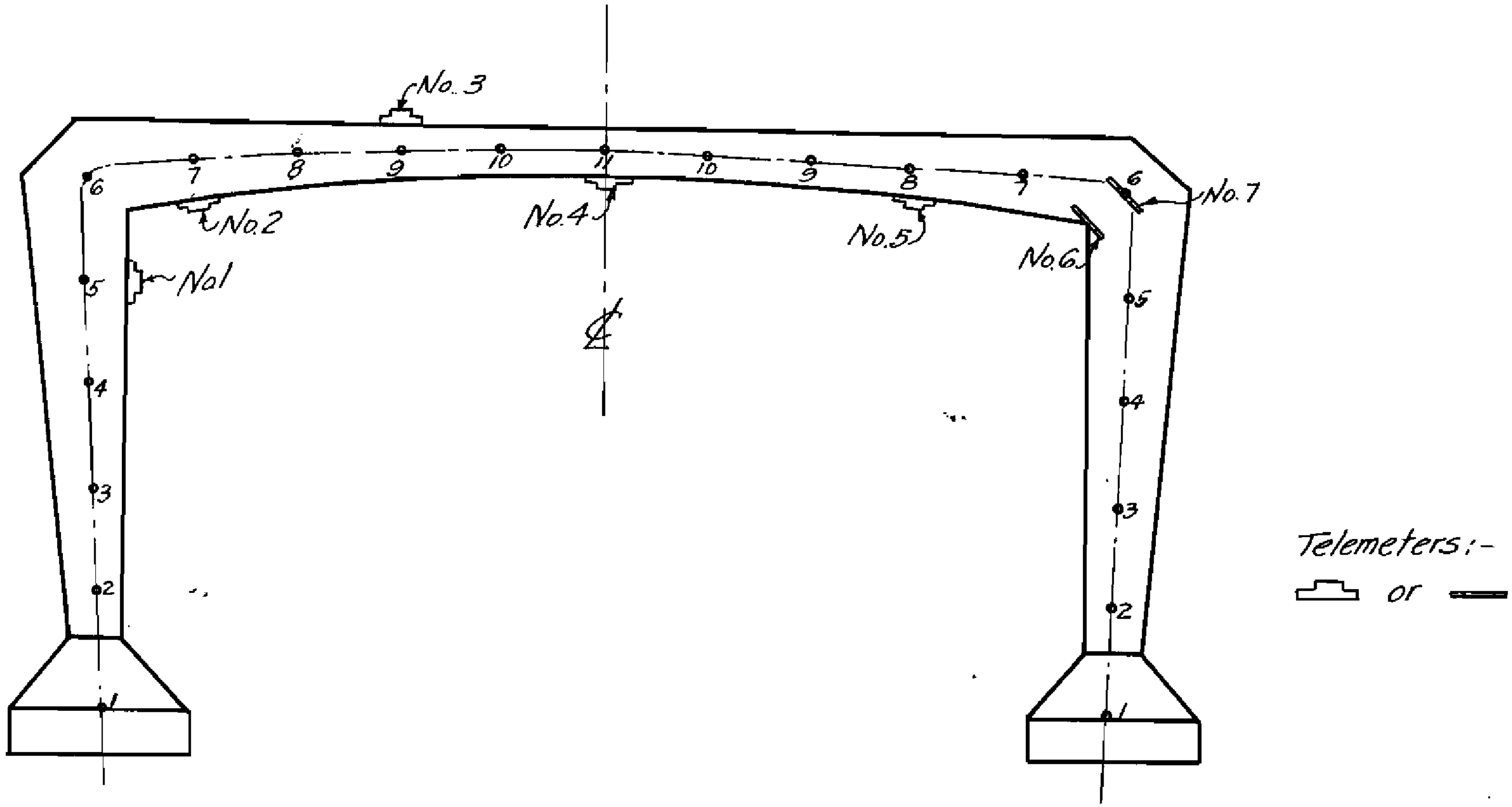
Strain gauge measurements were to be taken with telemeters so it was necessary to place telemeter plugs at the desired points in the bridge. This is accomplished by screwing the plugs to spacer bars, or templates, at the required distance apart and fastening the spacer bar into the face of the form at the spot where measurements are desired. Seven sets of telemeter plugs were used on the model. The placing of these plugs is shown in Fig. 11. It can be noticed that two sets were used at the knee on one side of the bridge. This was to measure the relative stresses at two points in order to determine the position of the neutral axis at the knee.

The conditions of the footings caused by the use of piles is somewhat a matter of speculation. Of course, complete fixity as in the case of anchorage to rock cannot be assumed but some fixity does occur.



Lodometers, Jack Type
A
3/4" ϕ Cables, with turn-buckles
3'-0"
3'-0"
1-4"x6"x7'-6"
2-4"x6" x 11'-8" Timbers
℄
A
2-5/8" ϕ Bolts, thru footing & 4"x6"x7'-6"
ELEVATION
Jack Type Lodometer
3/4" ϕ Cable
2-5/8" ϕ Bolts
4"x1/4"x0'-7" ℞
SECT. A-A
4"x6"x7'-6"
2-4"x6" x 11'-8"
2-5/8" ϕ Bolts
PLAN


FIGURE 10



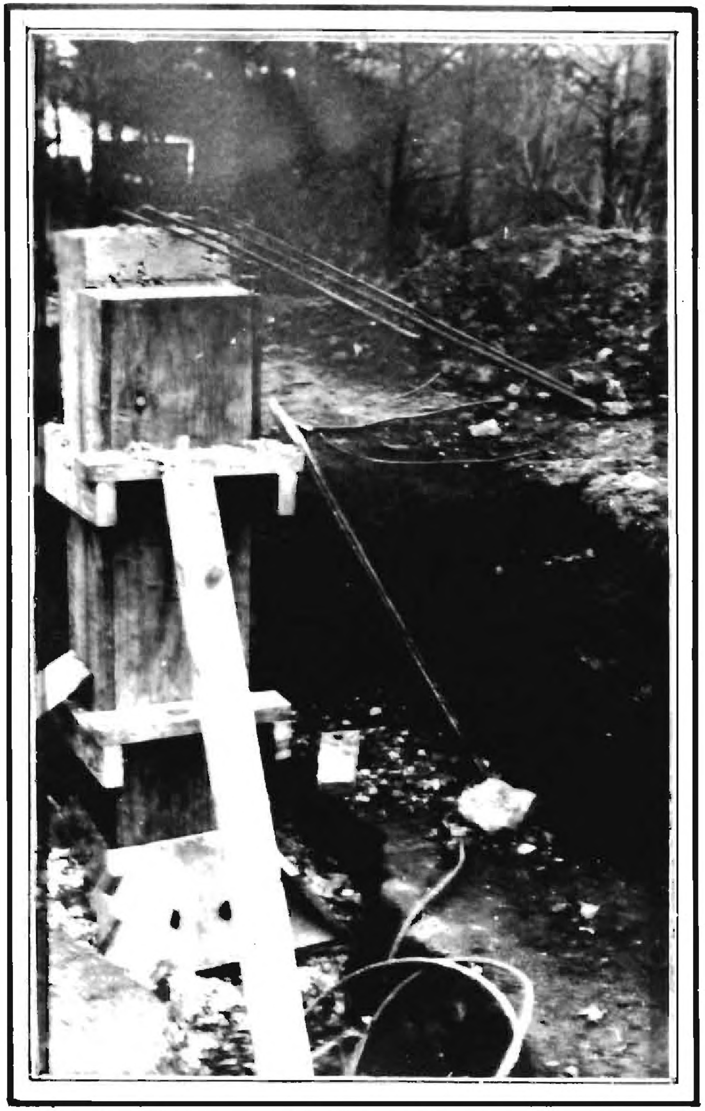

PLACING OF TELEMETERS

FIGURE 11.

The amount of this restraint and its effect on the stresses being problematical, it was desired to make an attempt to determine whether restraint from timber could be assumed. The fact that timber is more flexible, having a lower modulus of elasticity, makes it a matter of question whether or not the footing is allowed to deflect before the calculated moment necessary for restraint is developed. A 4"x6" timber about 7 ft. long was placed under each footing extending about 5 ft.back under the approach fills. A plate was placed under this timber, thru which 2- 5/8" ∅ bolts extended up thru the footing. A set of tests could then be run with the bolts free, the bond having been kept from the bolts by using tin cylinders around them. Then by screwing nuts on the bolts down tight the timbers exert a restraining moment and another set of tests could be run and the results compared. This can also be seen in Fig.10.

The bridge model was poured in the same order as one of larger proportions would be poured. The footings were poured as the first operation; key joints being made at their tops. Then the vertical legs were constructed with the tops stepped off as shown on the details of the model. Then the top of the frame forms the last operation.

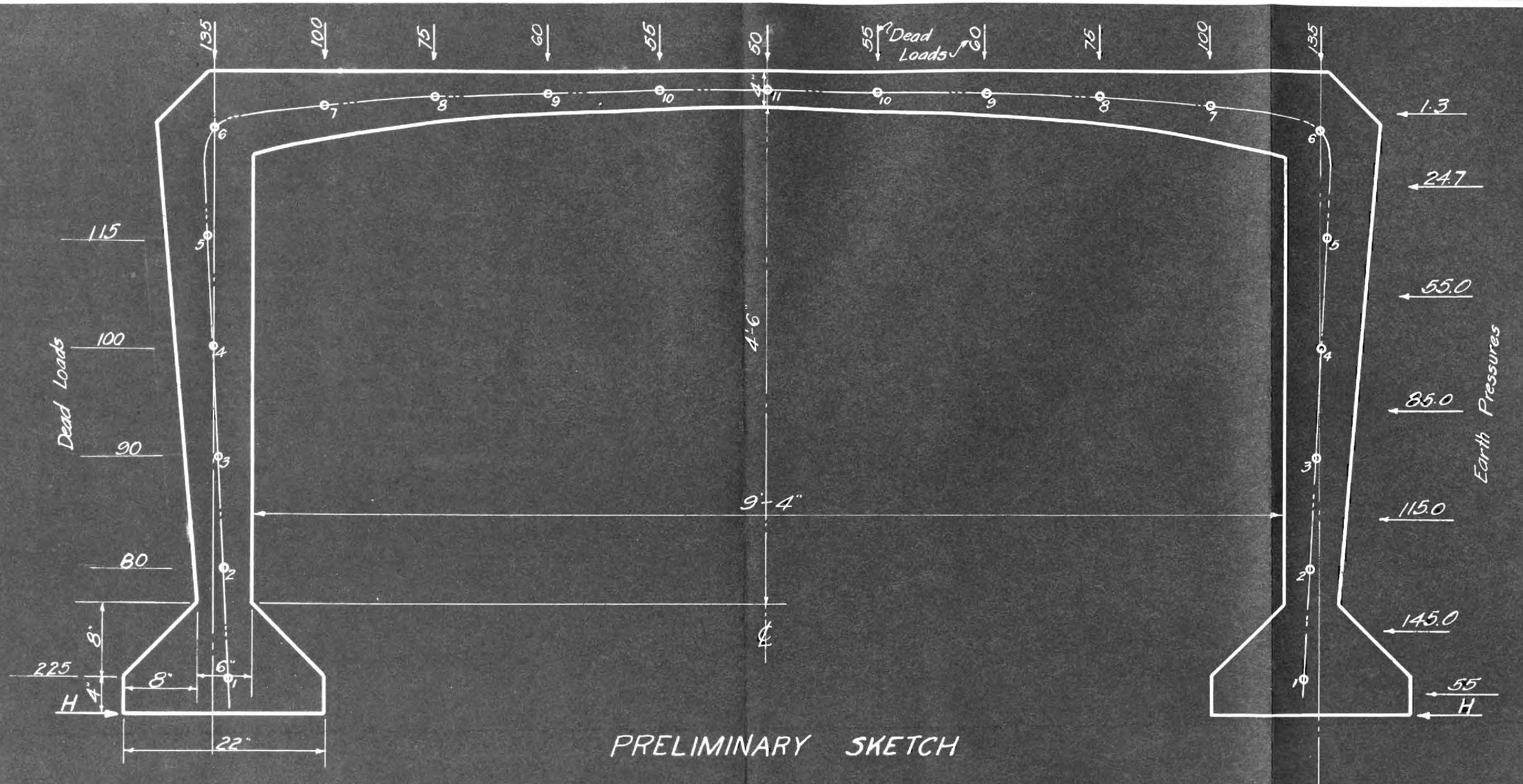
The complete design, including all calculations relative to the bridge model are included. The procedure is similar to that shown previously for the 81'-0" frame. It may be noticed that reinforcing was placed in the soffit fibers of the vertical legs, although no tension was calculated at this point under the design assumptions used. However, if the partial restraint at the footings



Vertical Leg Before Removing Forms.
Notice bolts projecting from footings.

Model After Forms Were Removed.

were realized this steel would be necessary. Experience has shown that the moment at the footings is developed in such a direction as to cause positive moment just above the footings. Also, nominal reinforcing was deemed advisable in the footings, placed so as to resist any tendency of the footings to crack off due to this restraining moment. Stirrups could have been used as an additional safety precaution in the top slab of the frame but were omitted because of the fact that difficulty would have been caused in pouring the concrete. As it was, the small dimensions of the model and the closeness of the reinforcing made the tamping of the concrete without disturbing the bars extremely difficult.




PRELIMINARY SKETCH

GA. SCHOOL OF TECHNOLOGY

SECTION OF
RIGID FRAME BRIDGE MODEL

Scale: 1" = 1'-0"　　June 1932

| Point | t Feet | $I_c$ 1/12 $t^3$ | $A_s$ Sq.Ft. | D $\frac{t}{2}$ - .125 | $I_s$ $10A_sD^2$ | I $I_o+I_s$ | Y | $\frac{Y^2}{I}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.833 | .5133 | .0027 | .792 | .0169 | .5302 | .33 | |
| 2 | .520 | .0117 | .0027 | .135 | .0005 | .0122 | 1.33 | 145.1 |
| 3 | .604 | .0184 | .0041 | .177 | .0013 | .0197 | 2.33 | 270.5 |
| 4 | .687 | .0270 | .0041 | .219 | .0020 | .0290 | 3.33 | 378.9 |
| 5 | .760 | .0366 | .0051 | .255 | .0033 | .0399 | 4.33 | 469.9 |
| 6 | .833 | .0482 | .0051 | .292 | .0043 | .0525 | 5.29 | 533.0 |
| 7 | .625 | .0203 | .0051 | .186 | .0018 | .0221 | 5.52 | 1379.0 |
| 8 | .479 | .0092 | .0033 | .115 | .0004 | .0096 | 5.60 | 3266.7 |
| 9 | .396 | .0052 | .0033 | .073 | .0002 | .0054 | 5.64 | 5890.7 |
| 10 | .354 | .0037 | .0041 | .052 | .0001 | .0038 | 5.66 | 8431.6 |
| 11 | .333 | .0031 | .0041 | .042 | .0001 | .0032 | 5.67 | 5023.4 |

$\sum =$ 25,788.8

$\sum \frac{Y^2}{I}$ for full span = 2x25,789 = 51,578

INFLUENCE LOAD = 10.

| Pt. | Influence Load at 7 R | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
| 1L | 0 | 0 | - .27 | - .27 |
| 2L | 0 | 0 | -1.09 | -1.09 |
| 3L | 0 | 0 | -1.91 | -1.91 |
| 4L | 0 | 0 | -2.73 | -2.73 |
| 5L | 0 | 0 | -3.55 | -3.55 |
| 6L | 0 | 0 | -4.34 | -4.34 |
| 7L | +1 | 249.8 | -4.53 | -3.53 |
| 8L | 2 | 1166.6 | -4.59 | -2.59 |
| 9L | 3 | 3133.2 | -4.62 | -1.62 |
| 10L | 4 | 5958.0 | -4.64 | - .64 |
| 11 | 5 | 8859.5 | -4.65 | + .35 |
| 10R | 6 | 8937.0 | -4.64 | +1.36 |
| 9R | 7 | 7310.8 | -4.62 | +2.38 |
| 8R | 8 | 4666.4 | -4.59 | +3.41 |
| 7R | 9 | 2248.2 | -4.53 | +4.47 |
| 6R | 0 | 0 | -4.34 | -4.34 |
| 5R | 0 | 0 | -3.55 | -3.55 |
| 4R | 0 | 0 | -2.73 | -2.73 |
| 3R | 0 | 0 | -1.91 | -1.91 |
| 2R | 0 | 0 | -1.09 | -1.09 |
| 1R | 0 | 0 | - .27 | - .27 |

$\Sigma$ = 42,529.5

$$H = \frac{42,529.5}{\frac{y^2}{I}} = .82$$

INFLUENCE LOAD = 10

| Pt. | Influence Load at 8R | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
| 1L | 0 | 0 | - .53 | -.53 |
| 2L | 0 | 0 | -2.13 | -2.13 |
| 3L | 0 | 0 | -3.73 | -3.73 |
| 4L | 0 | 0 | -5.33 | -5.33 |
| 5L | 0 | 0 | -6.93 | -6.93 |
| 6L | 0 | 0 | -8.46 | -8.46 |
| 7L | 2 | 499.6 | -8.83 | -6.83 |
| 8L | 4 | 2333.2 | -8.96 | -4.96 |
| 9L | 6 | 6266.4 | -9.02 | -3.02 |
| 10L | 8 | 11916.0 | -9.06 | -1.06 |
| 11 | 10 | 17719.0 | -9.07 | + .93 |
| 10R | 12 | 17674.0 | -9.06 | +2.94 |
| 9R | 14 | 14621.6 | -9.02 | +4.98 |
| 8R | 16 | 9332.8 | -8.96 | +7.04 |
| 7R | 8 | 1998.4 | -8.83 | - .83 |
| 6R | 0 | 0 | -8.46 | -8.46 |
| 5R | 0 | 0 | -6.93 | -6.93 |
| 4R | 0 | 0 | -5.33 | -5.33 |
| 3R | 0 | 0 | -3.73 | -3.73 |
| 2R | 0 | 0 | -2.13 | -2.13 |
| 1R | 0 | 0 | - .53 | - .53 |

$\sum$ = 82561.0

$$H = \frac{82561}{51,578} = 1.60$$

INFLUENCE LOAD = 10

| Pt. | Influence Load at 9R | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
| 1L | 0 | 0 | - .75 | - .75 |
| 2L | 0 | 0 | -3.01 | - 3.01 |
| 3L | 0 | 0 | -5.27 | - 5.27 |
| 4L | 0 | 0 | -7.53 | - 7.53 |
| 5L | 0 | 0 | -9.79 | - 9.79 |
| 6L | 0 | 0 | -11.96 | - 11.96 |
| 7L | 3 | 749.4 | -12.48 | - 9.48 |
| 8L | 6 | 3499.8 | -12.66 | - 6.66 |
| 9L | 9 | 9399.6 | -12.75 | - 3.75 |
| 10L | 12 | 17874.0 | -12.79 | - .79 |
| 11 | 15 | 26578.5 | -12.81 | ⨍ 2.19 |
| 10R | 18 | 26811.0 | -12.79 | ⨍ 5.21 |
| 9R | 21 | 21932.4 | -12.75 | ⨍ 8.25 |
| 8R | 14 | 8166.2 | -12.66 | ⨍ 1.34 |
| 7R | 7 | 1748.6 | -12.48 | - 5.48 |
| 6R | 0 | 0 | -11.96 | - 11.96 |
| 5R | 0 | 0 | - 9.79 | - 9.79 |
| 4R | 0 | 0 | - 7.53 | - 7.53 |
| 3R | 0 | 0 | - 5.27 | - 5.27 |
| 2R | 0 | 0 | - 3.01 | - 3.01 |
| 1R | 0 | 0 | - .75 | - .75 |

$\sum = 116,759.5$

$$H = \frac{116,759.5}{51,578} = 2.26$$

INFLUENCE LOAD = 10

| Point | Influence Load at 10R | | | |
|---|---|---|---|---|
| | Mom. | $\frac{My}{I}$ | Hy | Total Mom. |
| 1L | 0 | 0 | - .90 | - .90 |
| 2L | 0 | 0 | - 3.62 | - 3.62 |
| 3L | 0 | 0 | - 6.34 | - 6.34 |
| 4L | 0 | 0 | - 9.06 | - 9.06 |
| 5L | 0 | 0 | -11.78 | -11.78 |
| 6L | 0 | 0 | -14.39 | -14.39 |
| 7L | 4 | 999.2 | -15.01 | -11.01 |
| 8L | 8 | 4666.4 | -15.23 | - 7.23 |
| 9L | 12 | 12522.8 | -15.34 | - 3.34 |
| 10L | 16 | 25832.0 | -15.40 | + .60 |
| 11 | 20 | 35438.0 | -15.42 | + 4.58 |
| 10R | 24 | 35748.0 | -15.40 | + 8.60 |
| 9R | 18 | 18784.2 | -15.34 | + 2.66 |
| 8R | 12 | 6999.6 | -15.23 | - 3.23 |
| 7R | 6 | 1498.8 | -15.01 | - 9.01 |
| 6R | 0 | 0 | -14.39 | -14.39 |
| 5R | 0 | 0 | -11.78 | -11.78 |
| 4R | 0 | 0 | - 9.06 | - 9.06 |
| 3R | 0 | 0 | - 6.34 | - 6.34 |
| 2R | 0 | 0 | - 3.62 | - 3.62 |
| 1R | 0 | 0 | - .90 | - .90 |

$\sum = 140489.0$

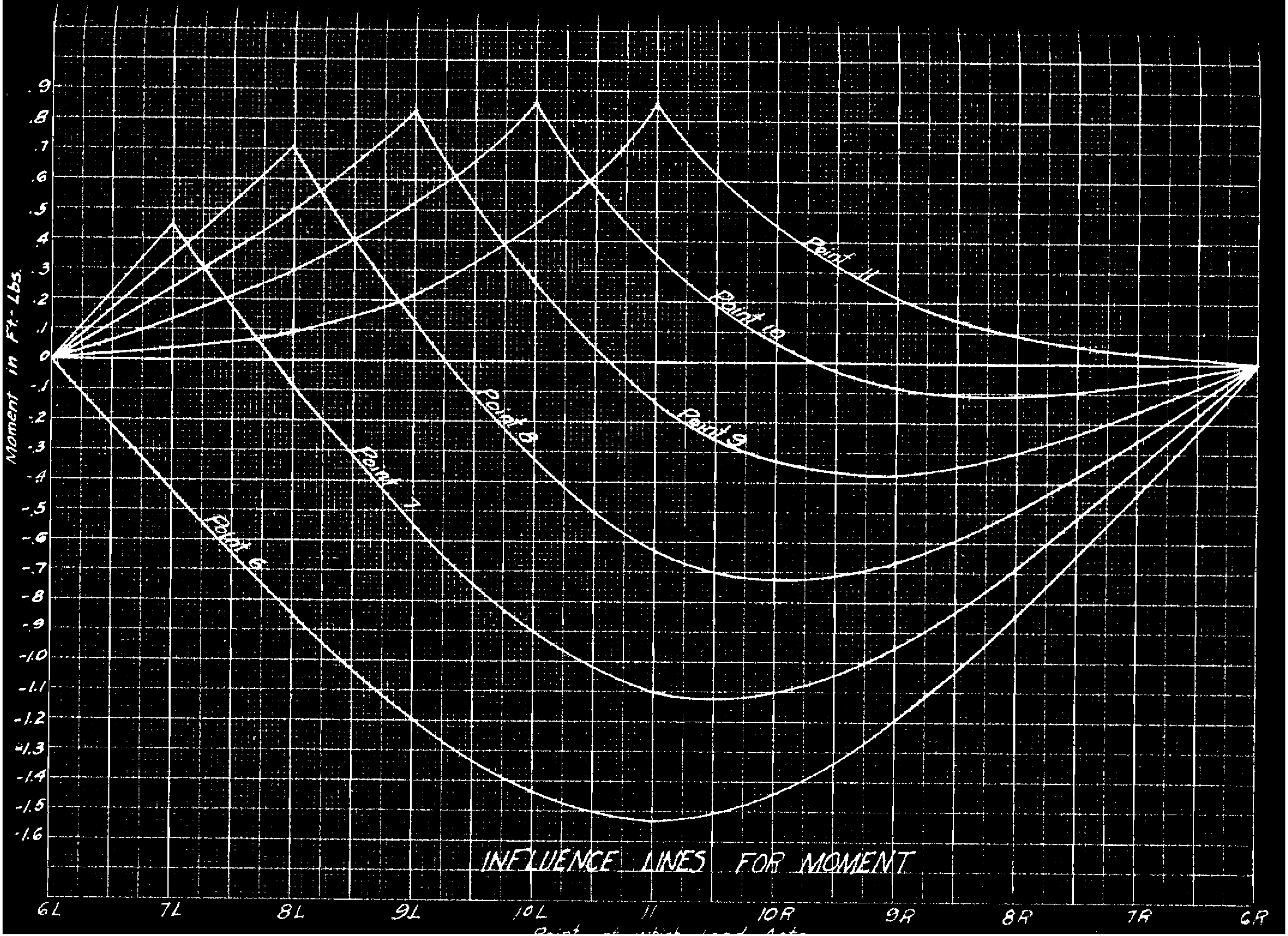
$$H = \frac{140,489}{51,578} = 2.72$$

Influence Load = 10

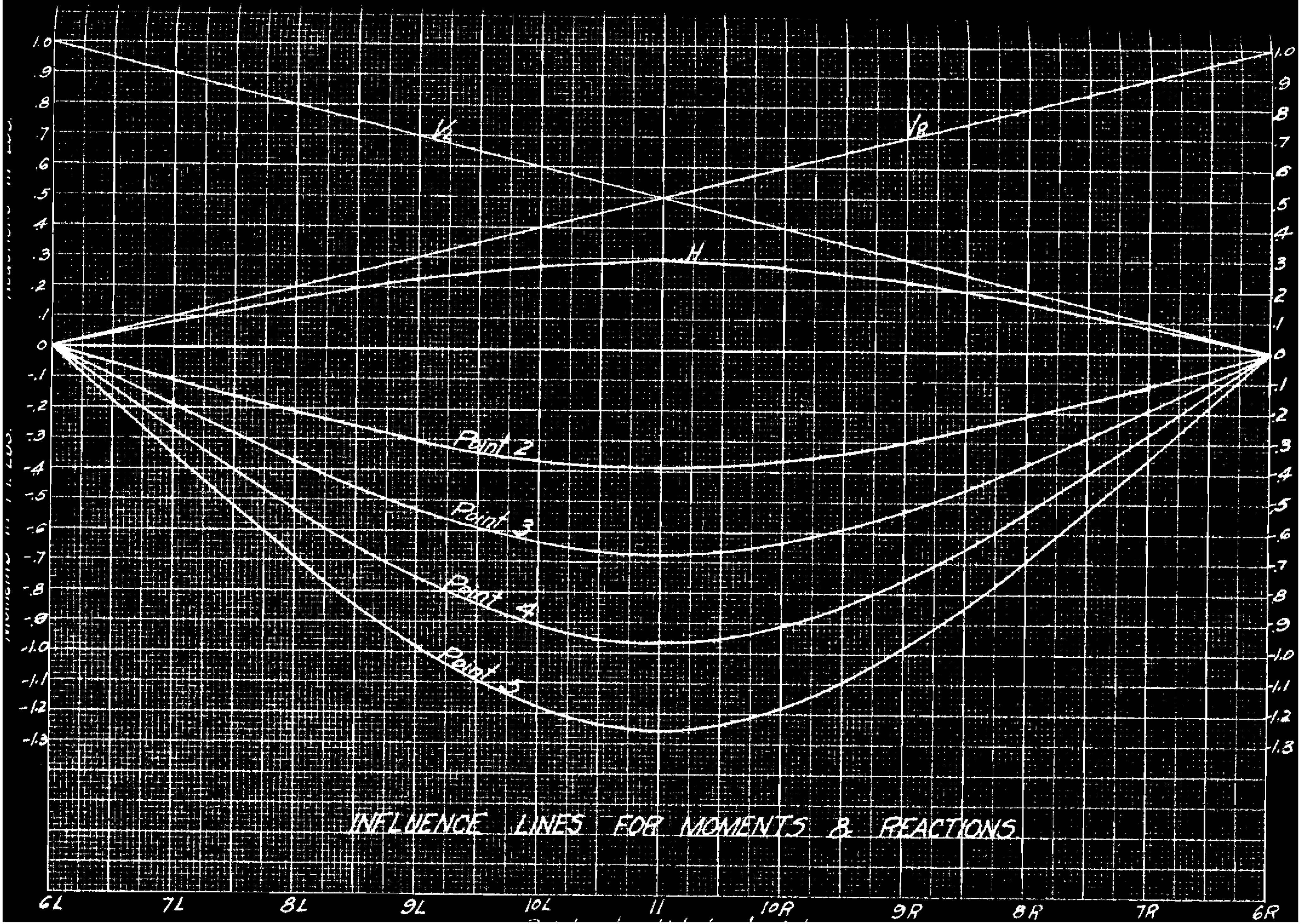
| Pt. | Mom. | $\frac{My}{I}$ | Hy | Total M |
|---|---|---|---|---|
| | INFLUENCE LOAD AT 11 | | | |
| 1 L | 0 | 0 | - .96 | - .96 |
| 2 L | 0 | 0 | -3.86 | -3.86 |
| 3 L | 0 | 0 | -6.76 | -6.76 |
| 4 L | 0 | 0 | -9.66 | -9.66 |
| 5 L | 0 | 0 | -12.56 | -12.56 |
| 6 L | 0 | 0 | -15.34 | -15.34 |
| 7 L | 5 | 1249.0 | -16.01 | -11.01 |
| 8 L | 10 | 5833.0 | -16.24 | - 6.24 |
| 9 L | 15 | 15666.0 | -16.36 | - 1.36 |
| 10 L | 20 | 29790.0 | -16.41 | + 3.59 |
| 11 | 25 | 44297.5 | -16.44 | + 8.56 |
| 10 R | 20 | 29790.0 | -16.41 | + 3.59 |
| 9 R | 15 | 15666.0 | -16.36 | - 1.36 |
| 8 R | 10 | 5833.0 | -16.24 | - 6.24 |
| 7 R | 5 | 1249.0 | -16.01 | -11.01 |
| 6 R | 0 | 0 | -15.34 | -15.34 |
| 5 R | 0 | 0 | -12.56 | -12.56 |
| 4 R | 0 | 0 | - 9.66 | - 9.66 |
| 3 R | 0 | 0 | - 6.76 | - 6.76 |
| 2 R | 0 | 0 | - 3.86 | - 3.86 |
| 1 R | 0 | 0 | - .96 | - .96 |

$\sum = 96835.5$

$H = \frac{96,835.5}{51,578} = 2.90$



Moment in Ft.-Lbs.
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
-1.6
Point 11
Point 10
Point 9
Point 8
Point 7
Point 6
INFLUENCE LINES FOR MOMENT
6L
7L
8L
9L
10L
11
10R
9R
8R
7R
6R



1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
$V_L$
$V_R$
H
Point 2
Point 3
Point 4
Point 5
INFLUENCE LINES FOR MOMENTS & REACTIONS.
6L
7L
8L
9L
10L
11
10R
9R
8R
7R
6R

RIGID FRAME MODEL

DEAD LOAD MOMENTS

| Load Pt. | Load | Point 2 MF | Point 2 M | Point 3 MF | Point 3 M | Point 4 MF | Point 4 M | Point 5 MF | Point 5 M | Point 6 MF | Point 6 M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7L | 100 | -.109 | - 10.9 | -.191 | -19.1 | -.273 | -27.3 | -.355 | -35.5 | -.434 | -43.4 |
| 8L | 75 | -.213 | - 15.98 | -.373 | -27.98 | -.533 | -39.98 | -.693 | -51.98 | -.846 | - 63.45 |
| 9L | 60 | -.301 | - 18.06 | -.527 | -31.62 | -.753 | -45.18 | -.979 | -58.74 | -1.196 | - 71.76 |
| 10L | 55 | -.362 | - 19.91 | -.634 | -34.87 | -.906 | -49.83 | -1.178 | -64.79 | -1.439 | -79.15 |
| 11 | 50 | -.386 | - 19.30 | -.676 | -33.80 | -.966 | -48.30 | -1.256 | -62.80 | -1.534 | -76.70 |
| 10R | 55 | -.362 | - 19.91 | -.634 | -34.87 | -.906 | -49.83 | -1.178 | -64.80 | -1.439 | -79.15 |
| 9R | 60 | -.301 | - 18.06 | -.527 | -31.62 | -.753 | -45.18 | -.979 | -58.74 | -1.196 | -71.76 |
| 8R | 75 | -.213 | - 15.98 | -.373 | -27.98 | -.533 | -39.98 | -.693 | -51.98 | - .846 | -63.45 |
| 7R | 100 | -.109 | - 10.9 | -.191 | -19.1 | -.273 | -27.3 | -.355 | -35.5 | - .434 | -43.4 |
| Totals- | | | -149.00 | | -261.04 | | -372.88 | | -484.82 | | -592.22 |

| Ld. Pt. | Load | Point 7 MF | Point 7 M | Point 8 MF | Point 8 M | Point 9 MF | Point 9 M | Point 10 MF | Point 10 M | Point 11 MF | Point 11 M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7L | 100 | +.447 | +44.7 | +.341 | +34.1 | +.238 | +23.8 | +.136 | +13.6 | +.035 | + 3.5 |
| 8L | 75 | -.083 | - 6.23 | +.704 | +52.80 | +.498 | +37.35 | +.294 | +22.05 | +.093 | + 6.98 |
| 9L | 60 | -.548 | -32.88 | +.134 | + 8.04 | +.825 | +49.50 | +.521 | +31.26 | +.219 | +13.14 |
| 10L | 55 | -.901 | -49.56 | -.323 | -17.17 | +.266 | +14.63 | +.860 | +47.30 | +.458 | +25.19 |
| 11 | 50 | -1.101 | -55.05 | -.624 | -31.20 | -.136 | - 6.80 | +.359 | +17.95 | +.856 | +42.80 |
| 10R | 55 | -1.101 | -60.56 | -.723 | -39.77 | -.334 | -18.37 | +.060 | + 3.30 | +.458 | +25.19 |
| 9R | 60 | -.948 | -56.88 | -.666 | -39.96 | -.375 | -22.50 | -.079 | - 4.74 | +.219 | +13.14 |
| 8R | 75 | -.683 | -51.23 | -.496 | -37.20 | -.302 | -22.65 | -.106 | - 7.95 | +.093 | + 6.98 |
| 7R | 100 | -.353 | -35.3 | -.259 | -25.9 | -.162 | -16.2 | -.064 | - 6.4 | +.035 | + 3.5 |
| | | | -302.99 | | -96.86 | | +38.76 | | +116.37 | | +140.42 |

D.L. NORMAL THRUSTS

V.R. = 1060#

| | | | | |
|---|---|---|---|---|
| Point 1 | N = 1060 | | Point 7 = | 112 |
| 2 | 835 | | 8 | 112 |
| 3 | 755 | | 9 | 112 |
| 4 | 665 | | 10 | 112 |
| 5 | 565 | | 11 | 112 |
| 6 | (450x0.71)+(112x.71) = 400 | | | |

Temperature Stresses

$e = .0000065$

$t = +45$ or $-35$

$E = 2{,}000{,}000 \times 144 = 288{,}000{,}000$ lbs./sq. ft.

$S = 1.0$

$$H = \frac{E_c t l}{S \sum \frac{y^2}{I}} = \frac{842{,}400}{51{,}578} = +16.3$$

$$H = -\frac{35}{45} \times 16.3 = -12.7$$

| Point | y | +Hy | -Hy |
|---|---|---|---|
| 2 | 1.33 | +21.68 | -16.89 |
| 3 | 2.33 | +37.98 | -29.59 |
| 4 | 3.33 | +54.28 | -42.29 |
| 5 | 4.33 | +70.58 | -54.99 |
| 6 | 5.29 | +86.23 | -67.18 |
| 7 | 5.52 | +89.98 | -70.10 |
| 8 | 5.60 | +91.28 | -71.12 |
| 9 | 5.64 | +91.93 | -71.63 |
| 10 | 5.66 | +92.26 | -71.88 |
| 11 | 5.67 | +92.42 | -72.01 |
| | | | |
| | | | |

Points 2 to 4, $N = 0$

Point 5

$+N = .71 \times 16.3 = +11.6$

$-N = .71 \times -12.7 = -10.0$

Points 6 to 11

$+N = +H = +16.3$

$-N = -H = -12.7$

RIB SHORTENING

| Point | N | t | $f_c$ #/sq." | $\Delta x$ | $f_c \Delta x$ |
|---|---|---|---|---|---|
| 2 | 5835 | .52 | 11,221 | 0 | - |
| 3 | 5755 | .604 | 9,528 | 0 | - |
| 4 | 5665 | .687 | 8,246 | 0 | - |
| 5 | 5565 | .760 | 7,322 | 0 | - |
| 6 | 5167 | .833 | 6,203 | 0 | - |
| 7 | 1826 | .625 | 2,922 | 1 | 2922 |
| 8 | 1826 | .479 | 3,812 | 2 | 7624 |
| 9 | 1826 | .396 | 4,611 | 3 | 13833 |
| 10 | 1826 | .354 | 5,158 | 4 | 20632 |
| 11 | 1826 | .333 | 5,483 | 5 | 13708 |

$\sum =$ 58719

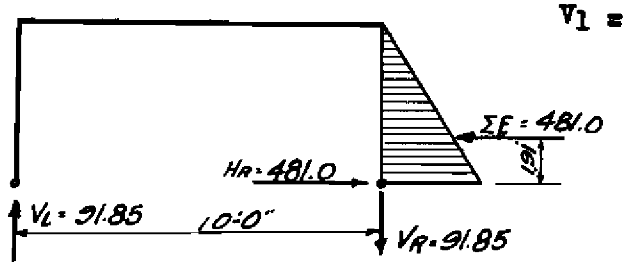
$f_c \Delta x$ for full span $= 2 \times 58719 = 117{,}438$

$$H = \frac{-\sum f_c \Delta x}{s \sum \frac{y^2}{I}} = - \frac{117{,}438}{51{,}578} = -2.28$$

| Point | y | Hy |
|---|---|---|
| 2 | 1.33 | - 3.03 |
| 3 | 2.33 | 5.31 |
| 4 | 3.33 | 7.59 |
| 5 | 4.33 | 9.87 |
| 6 | 5.29 | 12.06 |
| 7 | 5.52 | 12.59 |
| 8 | 5.60 | 12.77 |
| 9 | 5.64 | 12.86 |
| 10 | 5.66 | 12.90 |
| 11 | 5.67 | - 12.93 |

As can be seen, these values are negligible, so were ignored.

Earth Pressure-Right




$$V_l = V_r = \frac{481.0 \times 1.91}{10} = 91.85$$

Assume earth pressure = 30#/ sq.ft. (fluid)

| Point | Vertical Distance from 0 | Vertidal Distance Between | Earth Press. Rt. Hor. Loads: Loads | Sum of Loads | Inc. of Mom | Partial Mom A | Hor. Dist. From 0=X | Mom B = Vx | Sub-Total $M_a+M_b$ |
|---|---|---|---|---|---|---|---|---|---|
| HL | 0 | .167 | 481.0 | 481.0 | 80.3 | | 0 | 0 | 0 |
| E1 | .167 | .167 | 55.0 | 426.0 | 71.0 | + 80.3 | | | |
| 1R | .33 | .50 | - | 426.0 | 213.0 | + 151.3 | | | +151.3 |
| E2 | .83 | .50 | 145.0 | 281.0 | 140.5 | + 364.3 | | | |
| 2R | 1.33 | .50 | - | 281.0 | 140.5 | + 504.8 | | | +504.8 |
| E3 | 1.83 | .50 | 115.0 | 166.0 | 83.0 | + 645.3 | | | |
| 3R | 2.33 | .50 | - | 166.0 | 83.0 | + 728.3 | | | +728.3 |
| E4 | 2.83 | .50 | 85.0 | 81.0 | 40.5 | + 811.3 | | | |
| 4R | 3.33 | .50 | | 81.0 | 40.5 | +851.8 | | | + 851.8 |
| E5 | 3.83 | .50 | 55.0 | 26.0 | 13.0 | + 892.3 | | | |
| 5R | 4.33 | .48 | | 26.0 | 12.5 | + 905.3 | | | + 905.3 |
| E6 | 4.81 | .48 | 24.7 | 1.3 | 0.6 | + 917.8 | | | |
| 6R | 5.29 | .11 | | 1.3 | 0.1 | + 918.4 | | | + 918.4 |
| E7 | 5.40 | .12 | 1.3 | 0.0 | 0.0 | + 918.5 | | | |
| 7R | 5.52 | .08 | | | | + 918.5 | 1 | -91.8 | + 826.7 |
| 8R | 5.60 | .04 | | | | + 918.5 | 2 | -183.7 | + 734.8 |
| 9R | 5.64 | .02 | | | | + 918.5 | 3 | -275.5 | +643.0 |
| 10R | 5.66 | .01 | | | | + 918.5 | 4 | -367.4 | +551.1 |
| 11 | 5.67 | | | | | + 918.5 | 5 | -459.2 | +459.3 |
| 10L | 5.66 | | | | | +918.5 | 6 | -551.1 | +367.4 |
| 9L | 5.64 | | | | | +918.5 | 7 | -642.9 | +275.6 |
| 8L | 5.60 | | | | | +918.5 | 8 | -734.8 | +183.7 |
| 7L | 5.52 | | | | | +918.5 | 9 | -826.6 | + 91.9 |
| 6L | 5.29 | | | | | +918.5 | 10 | -918.5 | 0 |
| 5L | 4.33 | | | | | +918.5 | 10 | -918.5 | 0 |
| 4L | 3.33 | | | | | +918.5 | 10 | -918.5 | 0 |
| 3L | 2.33 | | | | | +918.5 | 10 | -918.5 | 0 |
| 2L | 1.33 | | | | | +918.5 | 10 | -918.5 | 0 |
| 1L | .33 | | | | | +918.5 | 10 | -918.5 | 0 |

RIGID FRAME MODEL
Earth Pressure-Right

(Cont)

| Point | Y | I | $\frac{My}{I}$ | Hy | Total Mom: $M_a+M_b+Hy$ |
|---|---|---|---|---|---|
| H1 | 0 | | | | |
| E1 | | | | | |
| 1R | 33 | .5302 | +94 | -27.8 | +123.5 |
| E2 | | | | | |
| 2R | 1.33 | .0122 | +55023 | -111.9 | +392.9 |
| E3 | | | | | |
| 3R | 2.33 | .0197 | +86158 | -196.0 | +532.3 |
| E4 | | | | | |
| 4R | 3.33 | .0290 | +97767 | -280.1 | +571.7 |
| E5 | | | | | |
| 5R | 4.33 | .0399 | +98285 | -364.2 | +541.1 |
| E6 | | | | | |
| 6R | 5.29 | .0525 | +92575 | -444.9 | +473.5 |
| E7 | | | | | |
| 7R | 5.52 | .0221 | +206675 | -464.2 | +362.5 |
| 8R | 5.60 | .0096 | +428509 | -471.0 | +263.8 |
| 9R | 5.64 | .0054 | +671549 | -474.3 | +168.7 |
| 10R | 5.66 | .0038 | +820808 | -476.0 | + 75.1 |
| 11 | 5.67 | .0032 | +813834 | -476.8 | - 17.5 |
| 10L | 5.66 | .0038 | +547206 | -476.0 | -108.6 |
| 9L | 5.64 | .0054 | +287837 | -474.3 | -198.7 |
| 8L | 5.60 | .0096 | +107152 | -471.0 | -287.3 |
| 7L | 5.52 | .0221 | +22975 | -464.2 | -372.3 |
| 6L | 5.29 | .0525 | 0 | -444.9 | -444.9 |
| 5L | 4.33 | .0399 | 0 | -364.2 | -364.2 |
| 4L | 3.33 | .0290 | 0 | -280.1 | -280.1 |
| 3L | 2.33 | .0197 | 0 | -196.0 | -196.0 |
| 2L | 1.33 | .0122 | 0 | -111.9 | -111.9 |
| 1L | .33 | .5302 | 0 | -27.8 | - 27.8 |
| | | | $\Sigma$ = 4338387 | | |

Normal Thrusts:

6R = (84.1-91.85).71 = -5.5

6L = (84.1+91.85).71 = +124.9

2R to 5R
N = -91.85

2L to 5L
N = +91.85

7R to 7L
N = 84.1

$$H = \frac{4338387}{51,578} = 84.1$$

RIGID FRAME MODEL

## LIVE LOAD MOMENTS

| Load Point | Load Lbs. | Point 2 MF | Point 2 M | Point 3 MF | Point 3 M | Point 4 MF | Point 4 M | Point 5 MF | Point 5 M |
|---|---|---|---|---|---|---|---|---|---|
| 8L | 1000 | -.213 | -213 | -.373 | -373 | -.533 | -533 | -.963 | -.693 |
| 11 | 1000 | -.386 | -386 | -.676 | -676 | -.966 | -966 | -1.256 | -1256 |
| 8R | 1000 | -.213 | -213 | -.373 | -373 | -.533 | -533 | - .693 | - 693 |
| | Totals - | | -812 | | -1422 | | -2032 | | -2642 |

| Load Point | Load Lbs. | Point 6 MF | Point 6 M | Point 7 MF | Point 7 M | Point 8 MF | Point 8 M | Point 9 MF | Point 9 M |
|---|---|---|---|---|---|---|---|---|---|
| 8L | 1000 | -.846 | -846 | -.083 | -83 | +.704 | +704 | +.498 | +498 |
| 11 | 1000 | -1.534 | -1534 | -1.101 | -1101 | -.624 | -624 | -.136 | -136 |
| 8R | 1000 | -.846 | -846 | -.683 | -683 | -496 | -496 | -.302 | -302 |
| | Totals - | | -3224 | | -1867 | | +704 | | +498 |
| | | | | | | | -1120 | | -438 |

| Load Point | Load Lbs. | Point 10 MF | Point 10 M | Point 11 MF | Point 11 M |
|---|---|---|---|---|---|
| 8L | 1000 | +.294 | +294 | +.093 | + 93 |
| 11 | 1000 | +.359 | +359 | +.856 | +856 |
| 8R | 1000 | -.106 | -106 | +.093 | + 93 |
| | Totals- | | +653 | | +1042 |
| | | | -106 | | |

L.L. Normal Thrusts
V.R = 1500#

Point 1- N = 1500
2 = 1500
3 = 1500
4 = 1500
5 = 1500
6 =(0.71x1500)+(0.71x610) = 1500
7 = 610
8 = 610
9 = 610
10 = 610
11 = 610

SUMMARY OF MAXIMUM MOMENTS
AND NORMAL THRUSTS

| Loading | Point 2 M | Point 2 N | Point 3 M | Point 3 N | Point 4 M | Point 4 N |
|---|---|---|---|---|---|---|
| Dead | -149.0 | 835 | -261.0 | 755 | -372.9 | 665 |
| Earth P.-Rt. | -111.9 | - 92 | -196.0 | - 92 | - 280.1 | - 92 |
| Earth P. Lt. | +392.9 | + 92 | +532.3 | + 92 | +571.7 | + 92 |
| | | | | | | |
| Sub-total | +132.0 | 835 | +75.0 | 755 | - 81.3 | 665 |
| -Live | -812.0 | | -1422.0 | | -2032.0 | |
| +Live | | 1500 | | 1500 | | 1500 |
| -Temp. | -16.9 | | -29.6 | | - 42.3 | |
| +Temp. | +21.7 | | +38.0 | | + 54.3 | |
| | -696.9 | 2335 | -1376.6 | 2255 | -2135.6 | |
| MAX.TOTAL | +153.7 | 835 | +113.0 | + 755 | | +2165 |

| Loading | Point 5 M | Point 5 N | Point 6 M | Point 6 N | Point 7 M | Point 7 N |
|---|---|---|---|---|---|---|
| Dead | -484.8 | 565 | -592.2 | 40.0 | -303.0 | +112 |
| Earth P.-Rt. | -364.2 | -92 | -444.9 | - 6 | -372.3 | + 84 |
| Earth Pr. Lt. | +541.1 | +92 | +473.5 | +125 | +362.5 | +84 |
| | | | | | | |
| Sub-total | -307.9 | 565 | -563.6 | 519 | -312.8 | 280 |
| -Live | -2642.0 | | -3224.0 | | -1867.0 | |
| +Live | | 1500 | | 1500 | | 610 |
| -Temp. | -55.0 | | -67.2 | - 10 | - 70.1 | -13 |
| +Temp. | +70.6 | | +86.2 | + 12 | + 90.0 | +16 |
| | -3004.9 | | -3854.8 | | -2249.9 | |
| Max.Total | | +2065 | | +2009 | | +877 |

RIGID FRAME MODEL
SUMMARY OF MAXIMUM MOMENTS
AND NORMAL THRUSTS

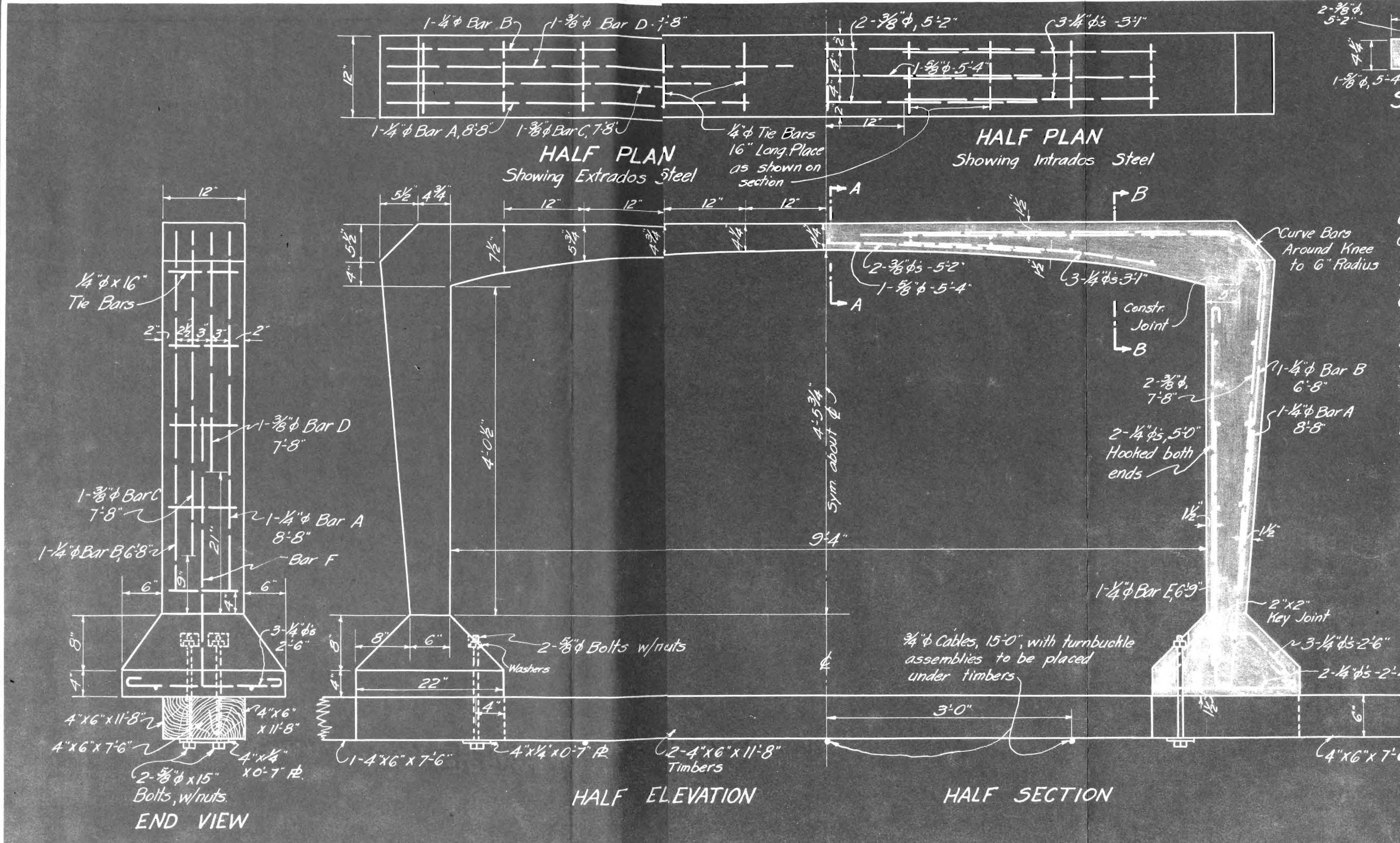
| Loading | Point 8 M | Point 8 N | Point 9 M | Point 9 N | Point 10 M | Point 10 N | POINT 11 M | POINT 11 N |
|---|---|---|---|---|---|---|---|---|
| Dead | -96.9 | 112 | +38.8 | 112 | + 116.4 | 112 | +140.4 | 112 |
| Earth P.-Rt. | -287.3 | 84 | +198.7 | 84 | - 108.6 | 84 | - 17.5 | 84 |
| Earth P.-Lt. | +263.8 | 84 | +168.7 | 84 | +75.1 | 84 | - 17.5 | 84 |
| | | | | | | | | |
| Sub-total | -120.4 | 280 | + 8.8 | 280 | + 82.9 | 280 | +105.4 | 280 |
| -Live | -1120.0 | 450 | -438.0 | 450 | - 106.0 | 160 | | |
| +Live | +704.0 | 160 | +498.0 | 160 | + 653.0 | 450 | +1042.0 | 610 |
| -Temp. | - 71.1 | - 13 | - 71.6 | - 13 | - 71.9 | - 13 | -72.0 | - 13 |
| +Temp. | + 91.3 | + 16 | + 91.9 | + 16 | + 92.3 | + 16 | + 92.4 | +16 |
| | | | | | | | | |
| | -1311.5 | 717 | -500.8 | 717 | - 95.0 | 427 | | |
| Max. Total - | +674.9 | 456 | -598.7 | 456 | +828.2 | 746 | +1239.8 | +906 |

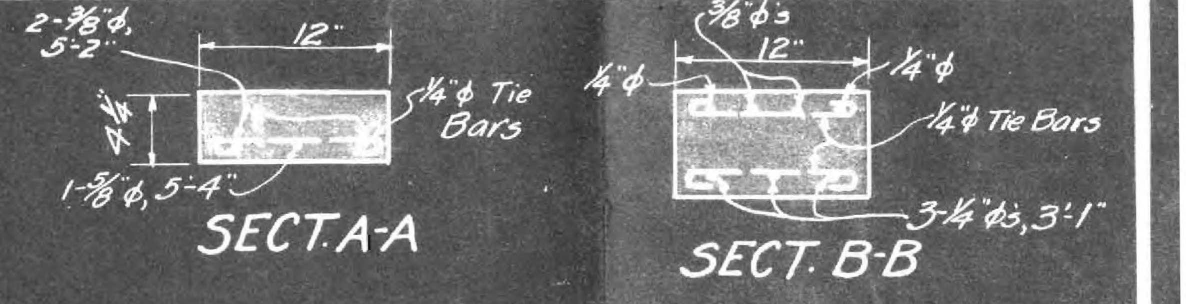
DESIGN OF SECTIONS

| Pt. | Moment Foot pounds | Moment Inch Pounds | N Lbs. | Arm-e =M÷N Inches | t Inches | d= t-1.5" | e' e+t/2-1.5" | e'/d | K= Ne'/bd^2 |
|---|---|---|---|---|---|---|---|---|---|
| 2 | -696.9 | - 8363 | 2335 | 358 | 6.25 | 4.75 | 5.21 | 1.10 | 54.1 |
| 2 | +153.7 | +1845 | 835 | 2.21 | 6.25 | 4.75 | 3.84 | .81 | 11.9 |
| 3 | -1376.6 | -16520 | 2255 | 7.33 | 7.25 | 5.75 | 9.46 | 1.65 | 53.9 |
| 3 | +113.0 | +1356 | 755 | 1.80 | 7.25 | 5.75 | 3.93 | .69 | 7.6 |
| 4 | -2155.6 | -25868 | 2165 | 11.93 | 8.13 | 6.63 | 14.50 | 2.19 | 59.6 |
| 5 | -3004.9 | -36059 | 2065 | 17.45 | 9.13 | 7.63 | 20.52 | 2.69 | 60.7 |
| 6 | -3854.9 | -46259 | 2009 | 22.10 | 10.00 | 8.50 | 25.60 | 3.01 | 59.4 |
| 7 | -2249.9 | -27000 | 877 | 30.78 | 7.50 | 6.00 | 33.03 | 5.50 | 67.0 |
| 8 | -1311.5 | -15738 | 717 | 21.95 | 5.75 | 4.25 | 23.33 | 5.50 | 77.3 |
| 8 | +674.9 | +8099 | 456 | 17.75 | 5.75 | 4.25 | 19.13 | 5.50 | 40.3 |
| 9 | -500.8 | -6010 | 717 | 8.38 | 4.75 | 3.25 | 9.26 | 5.50 | 38.3 |
| 9 | +598.7 | +7185 | 456 | 15.75 | 4.75 | 3.25 | 16.63 | 4.50 | 59.8 |
| 10 | - 95.0 | -1140 | 427 | 2.67 | 4.25 | 2.75 | 3.30 | 2.85 | 15.5 |
| 10 | +828.2 | +9939 | 746 | 13.30 | 4.25 | 2.75 | 13.93 | 5.12 | 114.5 |
| 11 | +1239.8 | +14878 | 906 | 16.40 | 4.25 | 2.75 | 17.03 | 1.20 | 169.9 |

| Point | $f_c$-pounds per sq. inch | $f_s$-pounds per sq. inch | Req'd p | Req'd. As Sq. In. | Bars to be Used |
|---|---|---|---|---|---|
| 2(-) | 430 | 16000 | .0007 | .040 | 1-1/4"Ø- |
| 2(+) | | | | | |
| 3(-) | 430 | 16000 | .0017 | .117 | 3-1/4"Ø's |
| 3(+) | | | | | |
| 4 | 450 | 16000 | .0025 | .199 | 1-3/8"Ø- 2-1/4"Ø's |
| 5 | 460 | 16000 | .0028 | .256 | 2-3/8"Ø's 2-1/4"Ø's |
| 6 | 450 | 16000 | .0029 | .296 | 2-3/8"Ø's 2-1/4"Ø's |
| 7 | 490 | 16000 | .0039 | .281 | 2-3/8"Ø's 2-1/4"Ø'S |
| 8(-) | 530 | 16000 | .0045 | .227 | 2-3/8"Ø's 1-1/4"Ø's |
| 8(+) | 350 | 16000 | .0022 | .112 | 3-1/4"Ø's |
| 9(-) | 350 | 16000 | .0018 | .070 | 1-3/8"Ø 1-1/4"Ø |
| 9(+) | 450 | 16000 | .0034 | .133 | 3-1/4" Ø's |
| 10(-) | | | | | |
| 10 + | 675 | 16000 | .0068 | .224 | 1-5/8"Ø 2-3/8"Ø's |
| 11 + | 800 | 11200 | .0157 | .518 | 1-5/8"Ø 2-3/8" Ø's |

These computations were made in this manner so as to be able to use diagram for bending and direct stress from Hool and Johnson's Concrete Engineer's Handbook.
Steel in compressive face ignored.




## GENERAL NOTES

Concrete: 1-2-3½ mix. Maximum size aggregate, 1".
Reinforcing of steel bars.
Cover on steel, 1½" unless noted.
Telemeter plugs and Level bar plugs to be placed in concrete as called for on special sketch.
Suitable timber bulkheads to be provided at both ends of bridge and approach fills placed in 1 ft. layers up to top of rib.

GA. SCHOOL OF TECHNOLOGY

DESIGN OF
RIGID FRAME BRIDGE MODEL

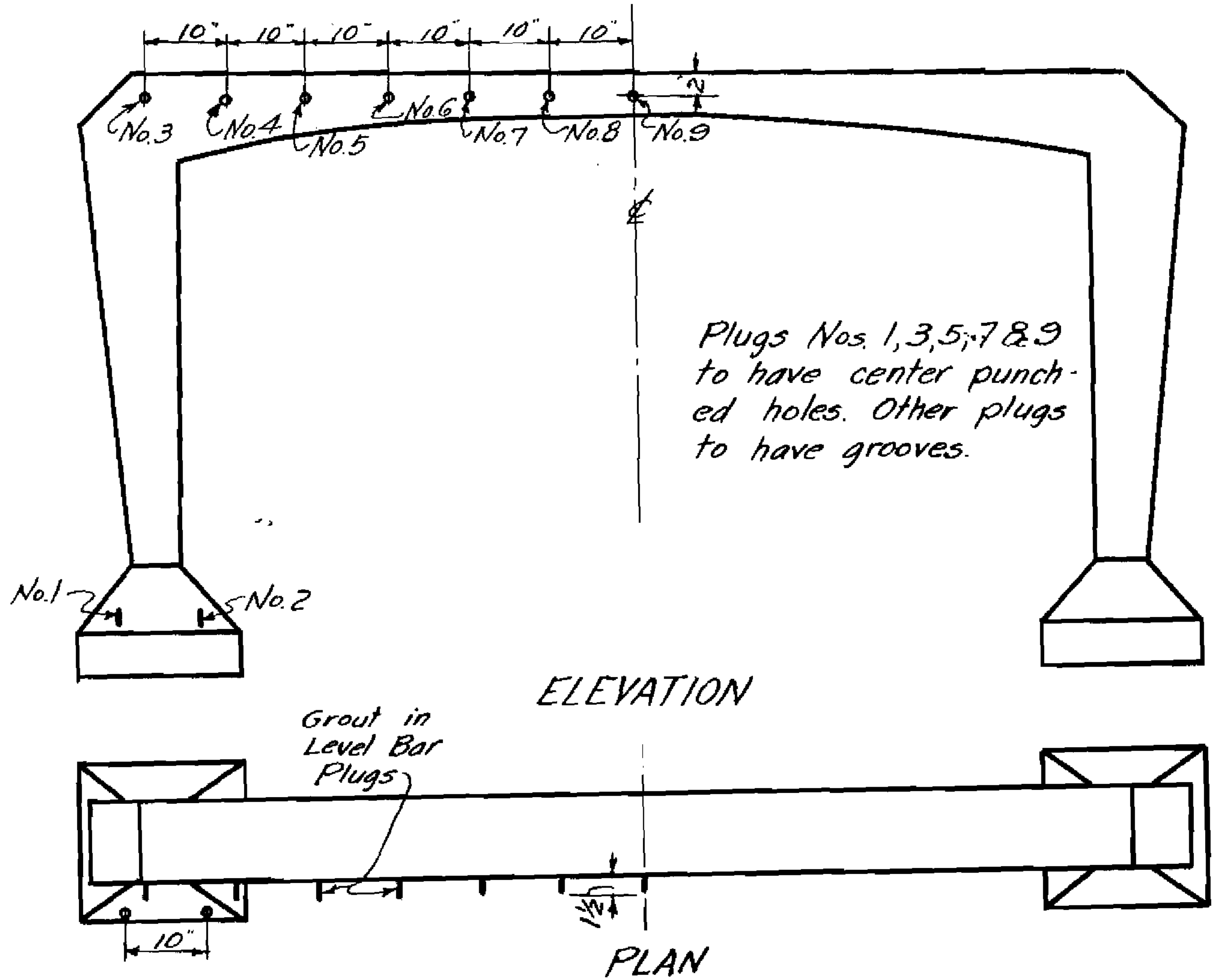
Scale: 1" = 1'-0"    June 1932

# CONCLUSIONS

## CONCLUSIONS

In order to measure the deflections of the rigid frame model under load it was decided to use a level bar. This instrument consists of a spirit level set in a frame about eleven inches long. At one end of the frame is a pointed projection extending about an inch below the bar and fastened securely to it. At the other end of the bar is a micrometer screw with a pointed projection from it extending down from the micrometer. The distance between these points is ten inches. The instrument is capable of measuring a change in deflection of one-one thousandth of an inch in ten inches. The measurement of change in elevation consists of placing the two points of the level bar on the two points whose relative elevations are required, with no load on the structure, and by using the micrometer screw, bringing the level bubble exactly to the center of the glass. Then the micrometer reading may be recorded. After the load is applied, the same procedure is carried out and the difference in the micrometer readings is the change in elevation between the two points. The test model was supplied with plugs at ten inches centers along the rib for half the span, on which to rest the points of the bar. Two plugs were also placed in the footing so that the rotation there could be measured.

These plugs were placed by drilling holes and grouting them in. A sketch of the placing of these plugs is shown in Figure 12. It will be noticed that alternate plugs are center punched and the others grooved. The grooves are to provide for temperature changes




PLACING OF LEVEL BAR PLUGS

FIGURE 12

and the resultant expansion or contraction.

The arrangement of the level bar plugs gives us a means of determining the deflections at all points of the span. The readings of the level bar give us the various deflections for a number of different loadings. Following are the readings for loads of varying magnitude at different points on the span, both with ends free and with the restraining moment at the footings developed. The differences of these readings from those for no load are the deflections. The maximum deflections are the sums of all the differences of readings having a negative sign.

Bridge Model under Construction
Vertical Legs Poured

View Showing General Shape of Rib.

LEVEL BAR READINGS

FREE ENDS

| Plugs | No Load | 1500# at Pt.11 | 2000# at Pt.11 | 2500# at Pt. 11 |
|---|---|---|---|---|
| 1-2 | .566 | .596 | .569 | .572 |
| 3-4 | .044 | .039 | .037 | .036 |
| 4-5 | .359 | .354 | .352 | .350 |
| 5-6 | .538 | .526 | .522 | .519 |
| 6-7 | .419 | .411 | .407 | .403 |
| 7-8 | .351 | .343 | .339 | .335 |
| 8-9 | .476 | .471 | .468 | .466 |

| Plugs | 3000# at Pt.11 | 2500# at Pt. 8L | 2500# at Pt. 8R | 1000# at Pts. 8L,11 and 8R |
|---|---|---|---|---|
| 1-2 | .572 | .571 | .569 | .572 |
| 3-4 | .033 | .035 | .040 | .034 |
| 4-5 | .347 | .351 | .355 | .349 |
| 5-6 | .517 | - | .527 | - |
| 6-7 | .399 | .415 | .411 | .406 |
| 7-8 | .332 | .349 | .344 | .338 |
| 8-9 | .464 | .477 | .468 | .467 |

FREE END CONDITIONS
LEVEL BAR READINGS

DIFFERENCES IN READINGS. -Readings = Inside going down.

Load at Pt. 11

| Plugs | 1500# | 2000# | 2500# | 3000# |
|---|---|---|---|---|
| 1-2 | +.003 | +.003 | +.006 | +.011 |
| 3-4 | -.005 | -.007 | -.008 | -.011 |
| 4-5 | -.005 | -.007 | -.009 | -.012 |
| 5-6 | -.006 | -.010 | -.013 | -.015 |
| 6-7 | -.008 | -.012 | -.016 | -.020 |
| 7-8 | -.008 | -.012 | -.016 | -.019 |
| 8-9 | -.005 | -.008 | -.008 | -.012 |

2500# at Pt. 8L

| | |
|---|---|
| 1-2 | +.003 |
| 3-4 | -.004 |
| 4-5 | -.004 |
| 5-6 | -.005 |
| 6-7 | -.008 |
| 7-8 | -.007 |
| 8-9 | -.008 |

2500# at Pt. 8R

| | |
|---|---|
| 1-2 | +.005 |
| 3-4 | -.009 |
| 4-5 | -.008 |
| 5-6 | - |
| 6-7 | -.004 |
| 7-8 | -.002 |
| 8-9 | +.001 |

1000# at Pts. 11,8R and 8L

| | |
|---|---|
| 1-2 | +.006 |
| 3-4 | -.010 |
| 4-5 | -.010 |
| 5-6 | - |
| 6-7 | -.013 |
| 7-8 | -.013 |
| 8-9 | -.009 |

LEVEL BAR READINGS

PARTIALLY FIXED ENDS

| Plugs | No Load | 1000# at Pt.11 | 1500# at Pt. 11 | 2000# at Pt.11 |
|---|---|---|---|---|
| 1-2 | .566 | .568 | .568 | .569 |
| 3-4 | .044 | .040 | .040 | .038 |
| 4-5 | .359 | .354 | .354 | .355 |
| 5-6 | .532 | .526 | .525 | .524 |
| 6-7 | .419 | .411 | .412 | .409 |
| 7-8 | .351 | .342 | .343 | .341 |
| 8-9 | .476 | .472 | .472 | .468 |

| Plugs | 2500# at Pt.11 | 2500# at Pt.8L | 2500# at Pt. 8R | 1000# at Pts.11,8L&8R |
|---|---|---|---|---|
| 1-2 | .571 | .568 | .571 | .569 |
| 3-4 | .037 | .040 | .035 | .036 |
| 4-5 | .350 | .355 | .351 | .349 |
| 5-6 | .519 | .527 | - | - |
| 6-7 | .404 | .413 | .416 | .407 |
| 7-8 | .336 | .344 | .349 | .339 |
| 8-9 | .468 | .469 | .477 | .468 |

FIXED END CONDITIONS
LEVEL BAR READINGS
DIFFERENCES IN READINGS

Load at Pt. 11

| Plugs | 1000# | 1500# | 2000# | 2500# |
|---|---|---|---|---|
| 1-2 | +.002 | +.002 | +.005 | +.005 |
| 3-4 | -.004 | -.004 | -.006 | -.007 |
| 4-5 | -.005 | -.005 | -.006 | -.009 |
| 5-6 | -.006 | -.007 | -.008 | -.013 |
| 6-7 | -.008 | -.007 | -.010 | -.015 |
| 7-8 | -.009 | -.008 | -.010 | -.015 |
| 8-9 | -.004 | -.004 | -.008 | -.008 |

2500# at Pt. 8L

| | |
|---|---|
| 1-2 | +.002 |
| 3-4 | -.004 |
| 4-5 | -.004 |
| 5-6 | -.005 |
| 6-7 | -.006 |
| 7-8 | -.007 |
| 8-9 | -.007 |

2500# at Pt. 8 R

| | |
|---|---|
| 1-2 | +.005 |
| 3-4 | -.009 |
| 4-5 | -.008 |
| 5-6 | - |
| 6-7 | -.003 |
| 7-8 | -.002 |
| 8-9 | +.001 |

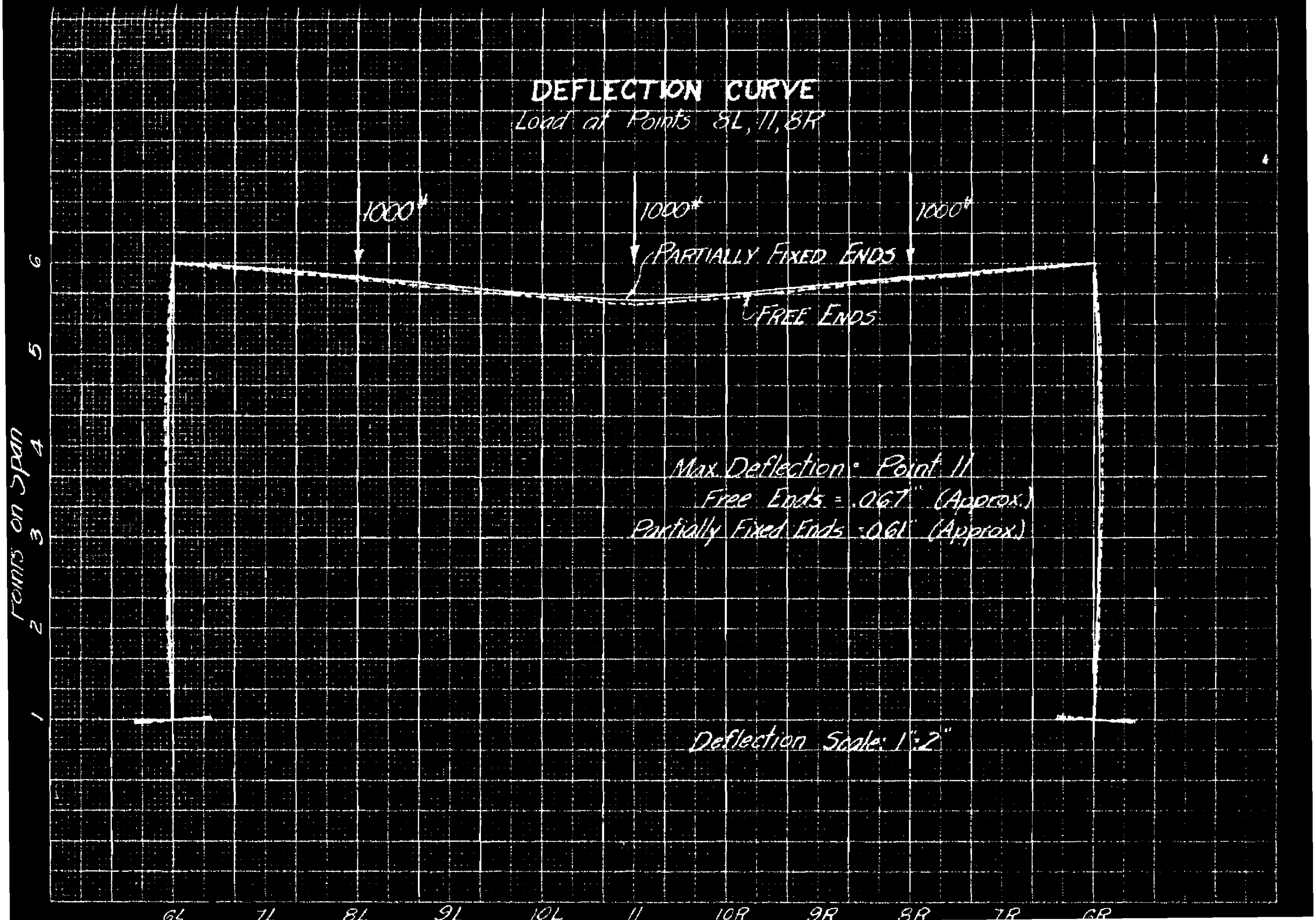
1000# at Pts. 8L, 8R and 11.

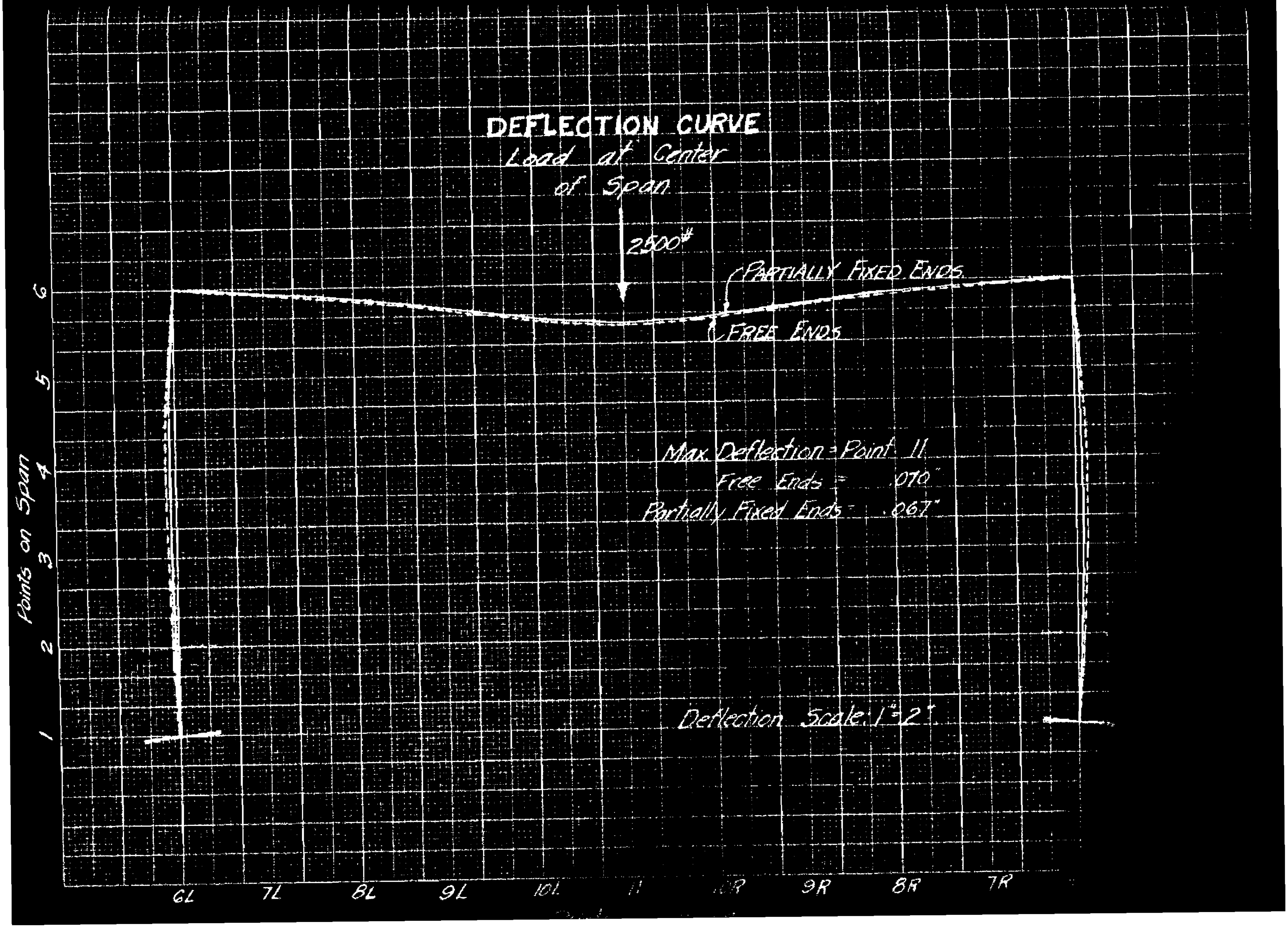
| | |
|---|---|
| 1-2 | +.003 |
| 3-4 | -.008 |
| 4-5 | -.010 |
| 5-6 | - |
| 6-7 | -.012 |
| 7-8 | -.012 |
| 8-9 | -.008 |

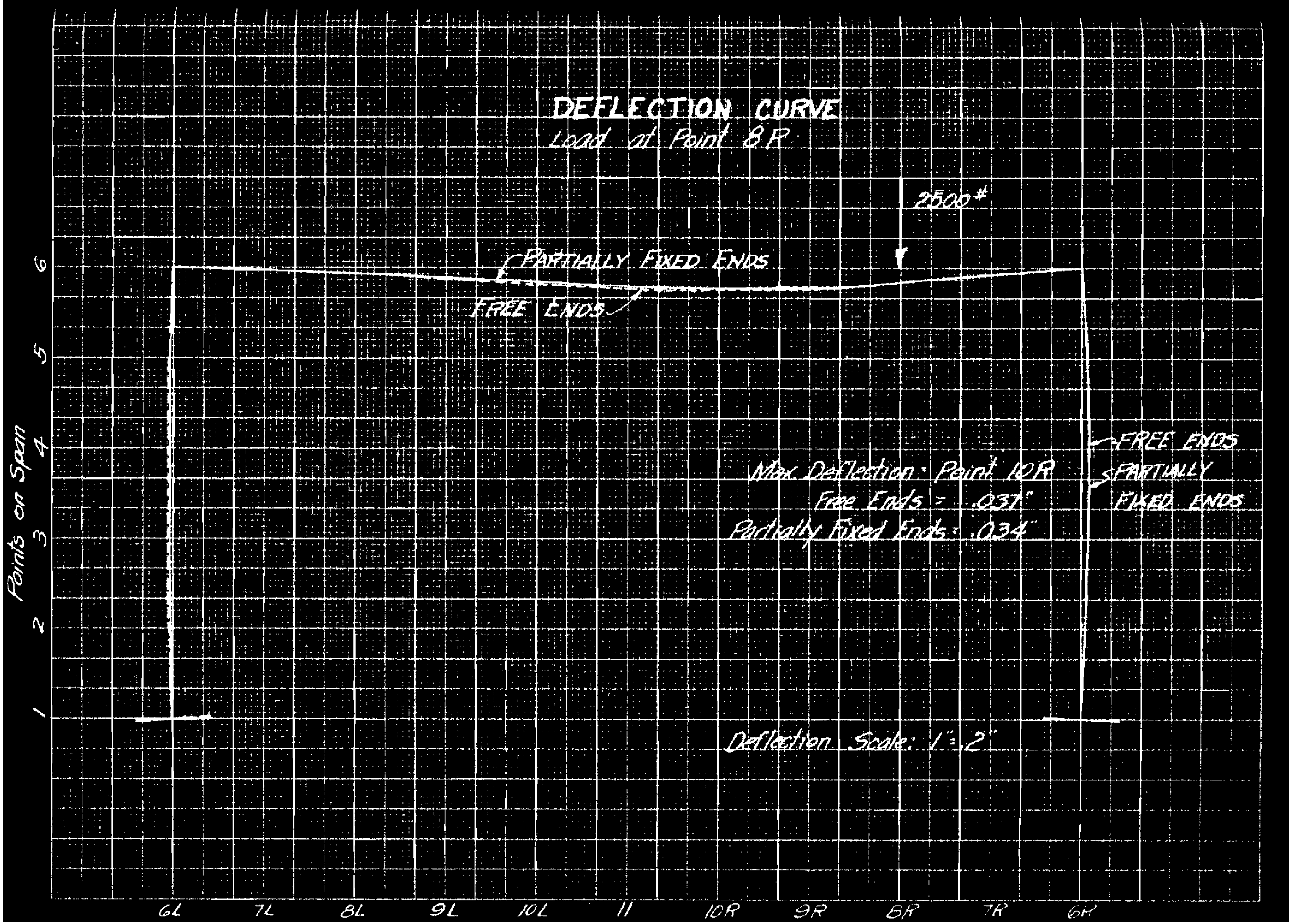
Note: Due to position of load, no reading for plugs 5-6 were obtained in some cases.

Since we have the rotation at the footings and the changes of elevation all along the rib it becomes a fairly simple procedure to approximate the general shape of the rigid frame bridge under load. However, the assumption must be made that the detail at the knee, assumed as a right angle, does not change. This would probably not be strictly true but the error is without doubt small. The general form of the deflection curves for a few of the loadings were plotted with an exaggerated deflection scale and are reproduced here.

The deflection curves for loadings with free ends and with footings partially restrained give us an excellent opportunity to notice the effect of the restraint. Due to the moment at the footings the fixed end frame does not rotate as much at the footings and this causes less bowing out of the vertical legs and consequently less deflection in the rib. From this it is evident that the timbers under the footings are actually exerting a restraining moment.


DEFLECTION CURVE
Load at Points 8L, 11, 8R
1000#
1000#
1000#
PARTIALLY FIXED ENDS
FREE ENDS
Max. Deflection: Point 11
Free Ends = .067" (Approx.)
Partially Fixed Ends = .061" (Approx.)
Deflection Scale: 1" = 2"
Points on Span
1
2
3
4
5
6
6L
7L
8L
9L
10L
11
10R
9R
8R
7R
6R


DEFLECTION CURVE
Load at Center of Span
2500#
PARTIALLY FIXED ENDS.
FREE ENDS
Max. Deflection = Point 11
Free Ends = .070"
Partially Fixed Ends = .067"
Deflection Scale: 1" = 2"
Points on Span
1
2
3
4
5
6
6L
7L
8L
9L
10L
11
9R
8R
7R



DEFLECTION CURVE
Load at Point 8R
2500#
PARTIALLY FIXED ENDS
FREE ENDS
FREE ENDS
PARTIALLY FIXED ENDS
Max Deflection: Point 10R
Free Ends = .037"
Partially Fixed Ends: .034"
Deflection Scale: 1" = .2"
Points on Span
1
2
3
4
5
6
6L
7L
8L
9L
10L
11
10R
9R
8R
7R
6R

Telemeter readings were taken for a number of different loadings at the three points on the span where the load could be applied. The seven instruments used gave readings with which the stress at almost all points on the rib and around the knee could be computed. These readings are reduced to stress by multiplying by a telemeter constant and by the modulus of elasticity of the material in which they represent the stress. The modulus of elasticity of the steel was assumed as 30,000,000 and that of the concrete 4,000,000. This value for concrete may seem a little high but the practice among engineers who use the modulus for reduction of stress seems to be to assume it of at least that value.

The calculations to locate the neutral axis at the knee were carried out and the results indicate, as determined by other tests, that its position is very close to the inside of knee. The assumptions made in these calculations can readily be seen by inspection of the sketch accompanying the computations. By using this position of the neutral axis the actual values for the stress given by telemeter No. 7 can be obtained.

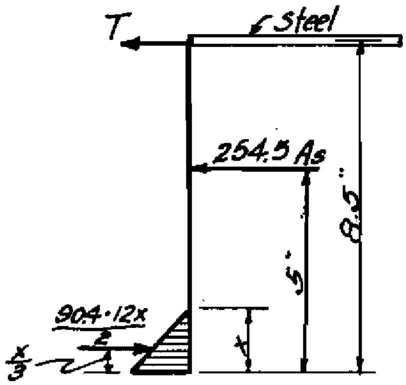
The theoretical stresses for a few of the loadings due to the live load were computed and compared with the observed stresses. These stresses seem to agree fairly well in some cases but in others they do not. It would appear that outside influences were active in a few cases, causing inaccurate readings. It might be well to state here that, due to the great sensitivity of the instruments, almost ideal conditions must be realized if exact readings are obtained. Variations of temperature are the greatest cause of this difficulty and care must be taken to protest the instruments from the sunshine.

## POSITION OF NEUTRAL AXIS

Average of Readings of Telemeter #6 = -90.4# / sq. in.

Average of readings of telemeter # 7 = +254.5 # / sq. in.

Consider the section diagonally across knee:




$$T = \frac{8.5}{5-X} \cdot 254.5A_s$$

$$M_c = \frac{90.4\cdot 12x}{2} \cdot \left(8.5-\frac{x}{3}\right)$$

$$M_s = T\left(8.5-\frac{x}{3}\right) = \frac{8.5}{5-x} \cdot 254.5A_s\left(8.5-\frac{x}{3}\right)$$

$$M_c = 4610.4x - 180.8x^2$$

$$M_s = \frac{5840}{5-x} - \frac{229.3x}{5-x}$$

$$M_c = M_s$$

$$4610.4x-180.8x^2 = \frac{5840}{5-x} - \frac{229.3x}{5-x}$$

$$23052x-4610.4x^2-904.0x^2+180.8x^3 = 5840-229.3x$$

$$180.8x^3-5514.4x^2+23{,}281.3x-5840 = 0$$

$$x^3-30.5x^2+128.8x-32.3 = 0$$

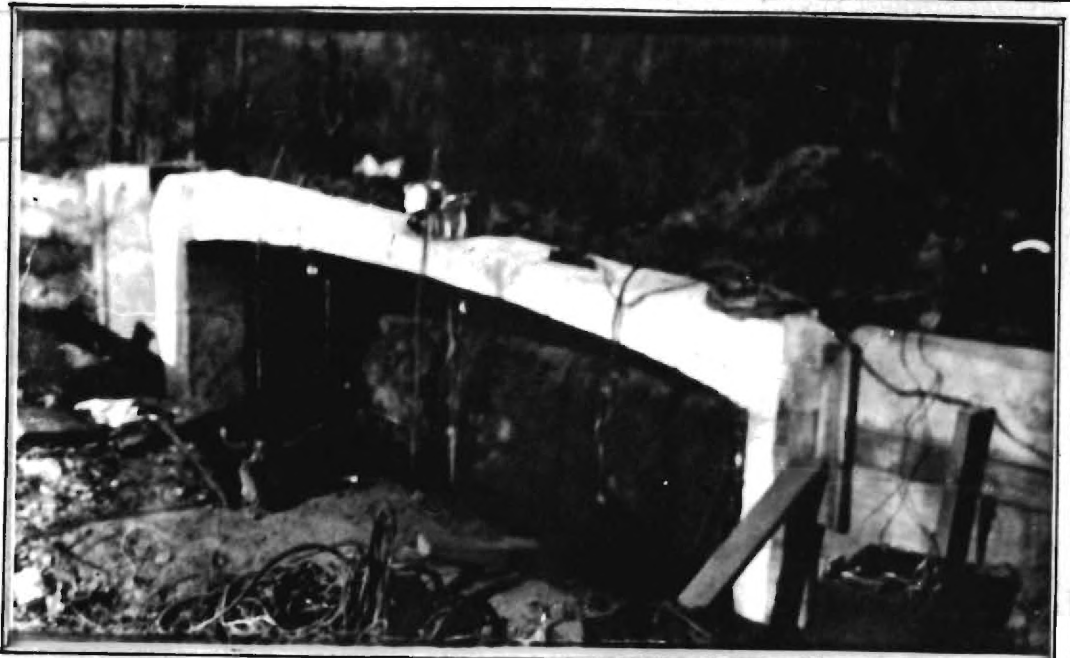
Solving $x = .27"$

$$jd = 8.5-.09 = 8.41"$$

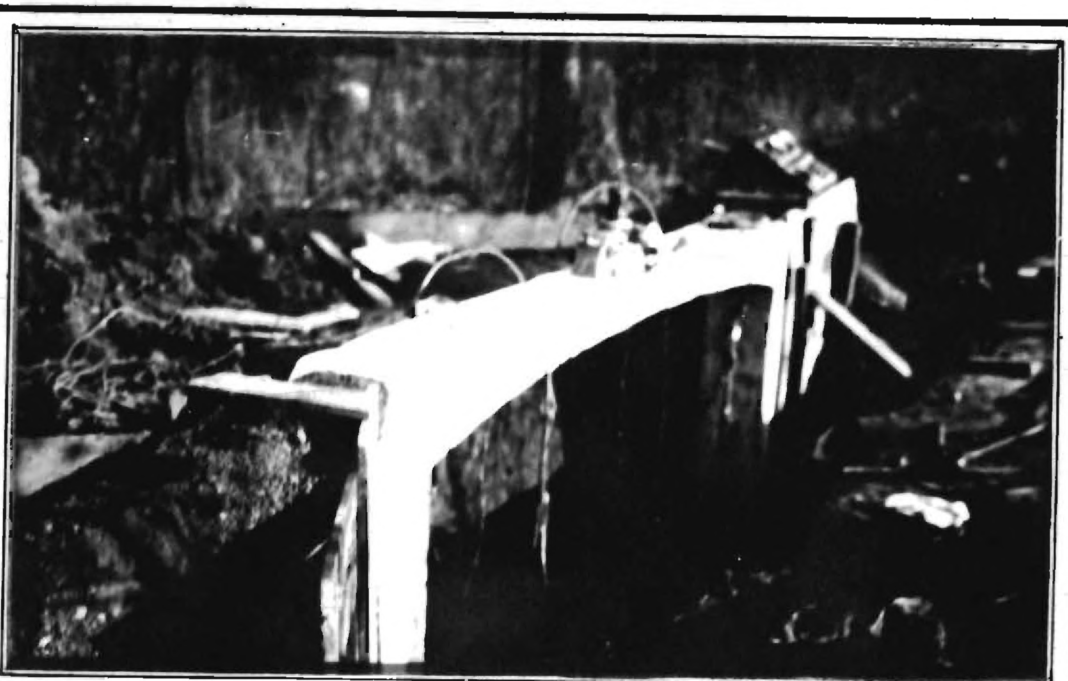
$$j = \frac{8.41}{8.5} = .989$$

$$K = \frac{.27}{8.5} = .032$$

Readings on telemeter No. 7 must be multiplied by $\frac{8.23}{5}$ to give stress in steel at point 6.



View Demonstrating How Load was
Applied to Model



Approach Fills at Ends
of Model in place

Following are given the readings and corresponding stresses for some of the loadings used. The comparisons of the calculated and observed stresses for a few of the loadings are tabulated also.

CALIBRATION OF TELEMETERS

| Telemeter No. | Point | Tension + | Compr. - | UNIT Strain + | Unit Stress + | Unit Strain - | Unit Stress- |
|---|---|---|---|---|---|---|---|
| 1 | 5 | .000130 | .000135 | .000016 | 480.0 | .000017 | 68.0 |
| 2 | 7 | .000157 | .000152 | .000020 | 600.0 | .000019 | 76.0 |
| 3 | 9 | .000139 | .000141 | .000017 | 510.0 | .000018 | 72.0 |
| 3 | 9 | .000148 | .000141 | .000019 | 570.0 | .000018 | 72.0 |
| 4 | 11 | .000169 | .000158 | .000021 | 630.0 | .000020 | 80.0 |
| 5 | 8 | .000147 | .000180 | .000018 | 540.0 | .000025 | 92.0 |
| 6 | 6 | .000133 | .000158 | .000017 | 510.0 | .000017 | 68.0 |
| 7 | 6 | .000111 | .000116 | .000014 | 420.0 | .000015 | 60.0 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

$E_c$ Assumed equal to 4,000,000 in above table

$E_s$ Assumed equal to 30,000,000

Two different instruments were used at Pt. 9 as can be seem from the above table. Some of the readings were taken one instrument and some on the other one.

## OBSERVED STRESSES

### LOADS AT CENTER OF SPAN

Free End Conditions

| Telemeter No. | | Load 1000# | 1500# | 2000# | 2500# | 3000# |
|---|---|---|---|---|---|---|
| 1 | Telemeter Reading | - 2.4 | - 3.8 | - 3.6 | - 6.0 | - 7.6 |
| | Stress | -163.2 | - 258.0 | -244.8 | -408.0 | -510.0 |
| 2 | Telemeter Reading | - 1.7 | - 4.0 | - 4.2 | - 6.8 | - 7.0 |
| | Stress | -129.2 | - 304.0 | -319.2 | -517.0 | -532.0 |
| 3 | Telemeter Reading | + 2.0 | + 6.0 | + 12.0 | + 12.5 | + 11.6 |
| | Stress | +1020.0 | +3060.0 | +6120.0 | +6380.0 | +5910.0 |
| 4 | Telemeter Reading | + 5.0 | + 14.7 | + 8.5 | + 15.0 | + 27.4 |
| | Stress | +3150.0 | +9252.0 | +5355.0 | +9450.0 | +15618.0 |
| 5 | Telemeter Reading | - 0.8 | - 4.0 | - 5.2 | - 7.5 | - 8.0 |
| | Stress | - 73.6 | - 371.0 | - 479.0 | - 690.0 | -736.0 |
| 6 | Telemeter Reading | - 0.2 | - 3.0 | - 4.4 | - 6.7 | - 8.5 |
| | Stress | - 27.2 | -204.0 | - 299.0 | - 456.0 | -528.0 |
| 7 | Telemeter Reading | + 0.2 | + 8.5 | + 1.0 | + 17.2 | + 7.0 |
| | Stress | +141.0 | +6000.0 | +706.0 | +12150.0 | +4940.0 |

PARTIALLY FIXED ENDS

| Telemeter No. | | LOAD 1000# | 1500# | 2000# | 2500# |
|---|---|---|---|---|---|
| 1 | Telemeter Reading | - 3.0 | - 5.8 | - 6.3 | - 8.3 |
| | Stress | - 204.0 | 394.0 | -428.0 | - 564.0 |
| 2 | Telemeter Reading | - 2.3 | - 5.0 | - 5.5 | - 7.2 |
| | Stress | - 174.8 | - 380.0 | -418.0 | -547.0 |
| 3 | Telemeter Reading | + 2.1 | + 7.3 | + 6.7 | + 12.3 |
| | Stress | +1197.0 | +4160.0 | +3820.0 | +7010.0 |
| 4 | Telemeter Reading | + 4.5 | + 12.3 | + 8.7 | +13.9 |
| | Stress | +2709.0 | +7750.0 | +5485.0 | +8760.0 |
| 5 | Telemeter Reading | - 1.4 | - 4.8 | - 5.5 | - 7.9 |
| | Stress | - 128.8 | -441.0 | - 506.0 | - 726.5 |
| 6 | Telemeter Reading | - 1.6 | - 5.7 | - 4.8 | - 9.2 |
| | Stress | - 108.8 | -286.0 | - 326.0 | - 625.0 |
| 7 | Telemeter Reading | + 0.3 | + 4.2 | + 9.3 | + 17.7 |
| | Stress | + 212.0 | +2970.0 | +6570.0 | +12500.0 |

CALCULATED AND OBSERVED STRESSES
DUE TO LIVE LOAD

1500# at center line of span

| Point | Moment Inch Pounds | N Pounds | Arm e = M÷N Inches | t Inches | d = t-1.5" | e' = e+t/2 -1.5" | e'/d | K = Ne'/bd² |
|---|---|---|---|---|---|---|---|---|
| 5 | -22680 | 1500 | 15.1 | 9.13 | 7.63 | 18.16 | 2.38 | 39.0 |
| 6 | -27540 | 1379 | 20.0 | 10.00 | 8.50 | 23.50 | 2.76 | 37.4 |
| 7 | -19800 | 443 | 44.7 | 7.50 | 6.00 | 46.95 | 7.82 | 48.1 |
| 8 | -11340 | 443 | 25.6 | 5.75 | 4.25 | 26.98 | 6.35 | 55.2 |
| 9 | -2430 | 443 | 5.5 | 4.75 | 3.25 | 6.38 | 1.96 | 22.2 |
| 11 | +15480 | 443 | 34.9 | 4.25 | 2.75 | 35.63 | 12.95 | 114.0 |

| Point | P | fc Pounds per sq. in. Calculated | fc Observ. | fs Pounds per sq. inch Calculated | fs Observed | Telemeter No. |
|---|---|---|---|---|---|---|
| 5 | .0038 | -275 | -258 | 7500 | | 1 |
| 6 | .0031 | -270 | -204 | 9000 | +6000 | 6-7 |
| 7 | .0044 | -330 | -304 | 10500 | | 2 |
| 8 | .0053 | -360 | -371 | 10000 | | 5 |
| 9 | .0049 | -125 | | 2800 | +3060 | 3 |
| 11 | .0160 | -850 | | 12000 | +9252 | 4 |

2500# at center line of span

| Point | Moment Inch Pounds | N Pounds | Arm e = M÷N Inches | t Inches | d = t-1.5" | e' = e+t/2 -1.5" | e'/d | K = Ne'/bd² |
|---|---|---|---|---|---|---|---|---|
| 5 | -37800 | 2500 | 15.1 | 9.13 | 7.63 | 18.16 | 2.38 | 65.0 |
| 6 | -45900 | 2292 | 20.0 | 10.00 | 8.50 | 23.50 | 2.76 | 62.4 |
| 7 | -33100 | 739 | 44.7 | 7.50 | 6.00 | 46.95 | 7.82 | 80.2 |
| 8 | -18920 | 739 | 25.6 | 5.75 | 4.25 | 26.98 | 6.35 | 92.1 |
| 9 | - 4050 | 739 | 5.5 | 4.75 | 3.25 | 6.38 | 1.96 | 37.0 |
| 11 | +25800 | 739 | 34.9 | 4.25 | 2.75 | 35.63 | 12.95 | 290.0 |

| Point | P | fc Pounds per sq. inch Calculated | fc Observed | fs Pounds per sq. inch Calculated | fs Observ. | Telemeter No. |
|---|---|---|---|---|---|---|
| 5 | .0038 | -460 | -408 | +12,000 | | 1 |
| 6 | .0031 | -490 | -456 | +15000 | +12150 | 6-7 |
| 7 | .0044 | -610 | -517 | +18,000 | | 2 |
| 8 | .0053 | -650 | -690 | +17000 | | 5 |
| 9 | .0049 | -230 | | + 5,000 | + 6380 | 3 |
| 11 | .0160 | -1320 | | +13,500 | + 9450 | 4 |

## OBSERVED STRESSES

1000 lbs. at Points 8L, 8R and 11.

FREE ENDS

| Telemeter No. | Telemeter Reading | Observed Stress |
|---|---|---|
| 1 | -4.3 | -292.0 |
| 2 | -5.8 | -441.0 |
| 3 | +0.3 | +153.0 |
| 4 | +14.8 | +9320.0 |
| 5 | -0.8 | - 73.6 |
| 6 | -5.3 | -360.0 |
| 7 | +4.8 | +3330.0 |

PARTIALLY FIXED ENDS

| Telemeter No. | Telemeter Reading | Observed Stress |
|---|---|---|
| 1 | -5.9 | -401.0 |
| 2 | -2.7 | -207.0 |
| 3 | +5.4 | +2750.0 |
| 4 | +10.7 | +6740.0 |
| 5 | -3.7 | -341.0 |
| 6 | -7.2 | -490.0 |
| 7 | +5.8 | +4015.0 |

## OBSERVED STRESSES
### FREE ENDS

2500 lbs. at Pt. 8R

| Telemeter No. | Telemeter Reading | Stress |
|---|---|---|
| 1 | -3.0 | -204.0 |
| 2 | -1.0 | -76.0 |
| 3 | +4.2 | +2142.0 |
| 4 | +2.0 | +1260.0 |
| 5 | -1.2 | - 110.4 |
| 6 | - | - |
| 7 | - | - |

2500 lbs. at Pt. 8L

| Telemeter No. | Telemeter Reading | Stress |
|---|---|---|
| 1 | -2.0 | -136.0 |
| 2 | -3.6 | -273.6 |
| 3 | +8.0 | +4080.0 |
| 4 | +2.0 | +1260.0 |
| 5 | +6.7 | +3610.0 |
| 6 | -1.6 | -108.8 |
| 7 | +2.0 | +1410.0 |

### PARTIALLY FIXED ENDS

2500 lbs. at Pt. 8R

| Telemeter No. | Telemeter Reading | Stress |
|---|---|---|
| 1 | -3.8 | -258.0 |
| 2 | -1.3 | - 98.8 |
| 3 | +3.7 | +2110.0 |
| 4 | +2.8 | +1765.0 |
| 5 | -0.2 | - 18.4 |
| 6 | -0.2 | - 13.6 |
| 7 | +0.5 | +346.0 |

2500 lbs. at Pt. 8L

| Telemeter No. | Telemeter Reading | Stress |
|---|---|---|
| 1 | -0.9 | -61.2 |
| 2 | -4.2 | - 319.0 |
| 3 | +0.9 | + 513.0 |
| 4 | +1.7 | +1070.0 |
| 5 | +7.6 | + 411.0 |
| 6 | -4.3 | - 292.0 |
| 7 | +8.7 | +6020.0 |

CALCULATED AND OBSERVED STRESSES
DUE TO LIVE LOAD

2500# at Pt. 8 R

| Point | Moment Inch-Pounds | N Pounds | Arm-e = M÷N Inches | t Inches | d =t-1.5" | e' = e+t-1.5"/2 | e'/d | K = Ne'/bd² |
|---|---|---|---|---|---|---|---|---|
| 5R | -20,850 | 2500 | 8.35 | 9.13 | 7.63 | 11.41 | 1.50 | 40.9 |
| 6R | -25,500 | 2060 | 12.37 | 10.00 | 8.50 | 15.87 | 1.87 | 37.8 |
| 7R | - 2,400 | 400 | 6.00 | 7.50 | 6.00 | 8.25 | 1.37 | 7.6 |
| 8R | +21,300 | 400 | 53.25 | 5.75 | 4.25 | 54.63 | 12.87 | 100.8 |
| 9R | +15,000 | 400 | 37.50 | 4.75 | 3.25 | 38.38 | 11.80 | 121.0 |
| 11 | + 2,700 | 400 | 6.75 | 4.25 | 2.75 | 7.38 | 2.68 | 32.5 |
| 9L | - 9,000 | 400 | 22.50 | 4.75 | 3.25 | 23.38 | 7.19 | 73.8 |
| 8L | -14,850 | 400 | 37.13 | 5.75 | 4.25 | 38.51 | 9.06 | 71.0 |
| 7L | -20,600 | 400 | 51.50 | 7.50 | 6.00 | 53.75 | 8.96 | 49.7 |
| 6L | -25,500 | 2060 | 12.37 | 10.00 | 8.50 | 15.87 | 1.87 | 37.8 |
| 5L | -20,850 | 2500 | 8.35 | 9.13 | 7.63 | 11.41 | 1.50 | 40.9 |

| Point | P | fc Pounds per sq. inch | | fs Pounds per sq. Inch | | Telemeter No. |
|---|---|---|---|---|---|---|
| | | Calculated | Observed | Calculated | Observed | |
| 5R | .0038 | -250 | -204 | +5000 | | 1 |
| 6R | .0031 | -280 | -108.8 | +7500 | +1410 | 6-7 |
| 7R | .0044 | - 50 | - 76 | +1000 | | 2 |
| 8R | .0053 | -750 | | +12000 | +3610 | 5 |
| 9R | .0049 | -900 | | +22000 | +2142 | 3 |
| 11 | .0060 | -150 | | +1500 | +1260 | 4 |
| 9L | .0049 | -540 | | +14500 | +4080 | 3 |
| 8L | .0053 | -500 | -110.4 | +13000 | | 5 |
| 7L | .0044 | -420 | -273.6 | +12300 | | 2 |
| 6L | .0031 | -280 | | +7500 | | 6-7 |
| 5L | .0038 | -250 | -136 | +5300 | | 1 |

The results of the tests indicated that the restraint caused by the timbers is of an appreciable amount and should be provided for in the design. The practice of using an intermediate design between the free end case and the fixed end case, when piles are used would seem to be safe. The telemeter readings for the case with partially fixed ends were greater in the region of the knee and less at the center of the span indicating a greater negative moment and a smaller positive moment, although the variations of the strain gage readings fail to evaluate these differences for us. The differences of deflections for the two cases would indicate the same conditions.

The calculated stresses were, in almost every case, of greater values than the corresponding observed stresses. This fact might be explained by the action of the earth fills at the ends of the bridge. Although no exact value can be assigned to this pressure, it is evident that a passive earth pressure must be developed by these fills. When the vertical legs deflect outward the action of the earth in resisting this movement is equivalent to an active pressure on the frame. From the amount of the differences in the calculated and observed stresses the amount of this passive presuue would seem to be quite large. This, of course, is on the assumption that the earth pressure accounts for all of the difference, which fact may not be entirely true.

An attempt was made to load the model to destruction but, with the available equipment, sufficient load could not be applied to cause a failure. A load of 6000 lbs. was applied at the center of the span, but due to the large deflection in the timbers under the bridge the range of the jack type lodometer prevented the addition of more load. Under the load of 6000 lbs. hair cracks over the tension reinforcement could be discerned at the center of the span.

The rigid frame bridge model demonstrated to the writer a remarkable strength and rigidity, considering the slender proportions of the structure. The economies affected by the rigid frame bridge are easily seen. When we couple that important fact with the consideration of its grace and symmetry, there can be small wonder that it is rapidly gaining popularity as one of the finest types of short span bridges.